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AN ANTENNA RADIATION PATTERN MEASURING RESEARCH INSTRUMENT

The PSL/NMSU Antenna Range

H. W. Haas

Contracts: NAS 5-503, 5-1032
AFCRL Through NAS 5-503
NORD 16710
Grant No. DA-ORD-31-124-60-G66

1 April 1963

NEW MEXICO STATE UNIVERSITY
PHYSICAL SCIENCE LABORATORY
UNIVERSITY PARK, NEW MEXICO

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ABSTRACT

This report covers the general aspects of a multi-purpose antenna radiation pattern measuring instrument designed, fabricated, instrumented and placed in operation during the early part of 1962. Initial planning began in late 1958 when it was apparent that the need for such an instrument was evident to support present and future electromagnetic programs of national interest. It is one of the finest antenna ranges in the country today and is expected to serve the country's needs for many years to come.

The endeavor was jointly supported by various agencies for which the Physical Science Laboratory conducts research and development work.

ACKNOWLEDGEMENTS

The technical and economic requirements of this endeavor were such that many agencies supported the project in a joint effort, thus obtaining a very versatile precision instrument at a relatively nominal cost to each agency, which in turn will serve the needs of all for many years to come. The Physical Science Laboratory, New Mexico State University, is deeply appreciative of the support and cooperation provided by the following agencies:

The National Aeronautics and Space Administration
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FOREWORD

This final report on the establishment of the Physical Science Laboratory Antenna Radiation Pattern Measuring Instrument at New Mexico State University, University Park, New Mexico is final only in the sense that all of the initial program objectives have been completed together with several others phased into the program since the preliminary planning began in 1958. Included in the overall objectives were provisions for future expansion as the need arises particularly with regard to land, electric power, roads, instrumentation and logistics all of which are compatible in every foreseeable way with the various pattern ranges provided for within the scope of this effort and established to date. It is therefore appropriate at this time for contractural, documentary and information dissemination purposes to report what has been accomplished and is available to all concerned.

The chief aims of the Physical Science Laboratory, since its inception in 1946, are:

a. To contribute to the national effort.

b. To promote continued improvement in the quality and quantity of the scientific teaching and research staff of the University.

c. To provide part-time employment for deserving students.

The research instrument described in the pages that follow is dedicated toward fulfilling these aims.

1.0 INTRODUCTION

The purpose of establishing an improved high capacity precision antenna radiation pattern measuring instrument is to provide this country and the various organizations therein, for which this laboratory conducts research and development work, with a versatile instrument to be employed in general and special areas of electromagnetic research, design, development and engineering endeavor.

The nature of this report is general in form rather than to include the details of several thousand pages of the pattern range operations manual, equipment manuals, drawings, etc., which are being continually added to, revised and updated. For such detailed information, the reader is invited to contact the laboratory directly.

The primary purpose of this report is to provide general information to all concerned about the antenna range and its capabilities. Remarks will be included, where appropriate, to provide additional clarity or emphasis.

The first portion of the report will be directed toward the general arrangement of the major portions of the several ranges. The second portion will review in greater detail the major subsystems and components with appropriate comments and photographs where necessary.

The reader should also be aware that many of the major and minor subsystems are functional, as desired, on several legs of the antenna range because of interchangeable features and versatility designed into the system. Accordingly emphasis will be placed upon the function of the range and associated instrumentation. For example; the model range antenna positioner may be physically placed on any of the three other azimuth antenna positioner turntables on different legs of the range to meet a particular or special requirement. Similarly the recorder consoles or portions thereof may be relocated, at will, to different stations in accord with a subsystem plug-in concept for maximum interchangeability, operational versatility and reliability.

2.0 GENERAL FUNCTIONAL REQUIREMENTS

2.1 The basic requirement was to design, build and instrument an antenna radiation pattern measuring range capable of accurately and rapidly measuring the free-space distant-field pattern of an antenna in the radio frequency spectrum from 100 Mc to 75 Gc. The range is primarily designed to accomplish the required antenna pattern and polarization measurements at full scale. Provisions are also included for measuring phase front characteristics of a radiator over a portion of the radio frequency spectrum.

2.2 Accuracy of radiation pattern measurements is of paramount importance. With this point always in the forefront of the design criteria, it is necessary to achieve a system which has the capacity to make measurements rapidly. Provisions must be made to accomplish setup and calibration requirements in the shortest time possible. Once the range is "ready" for the actual measurements, the instrumentation and procedure must permit the required number of pattern recordings to be made as fast as possible with a minimum amount of intervening dead time, i.e., consistent with personnel safety, safe, rapid and accurate motion of machinery and related instrumentation. A third objective is to design and otherwise provide for a system requiring minimum maintenance and ease of maintenance, thus contributing toward maximum efficiency for many years in the future.

2.3 Radiation pattern data obtained from the range must be of a quality and form to permit immediate reproduction for the transmittal of data and/or direct inclusion into formal report channels. No smoothing or replotting or radiation pattern data is permitted. Last, but of prime importance, is a well-trained operations staff to conduct measurements and coordinate all activities of the appropriate range legs to effect maximum use time and no interference.

3.0 GENERAL PROPAGATION PATH REQUIREMENTS

3.1 In designing any radiation pattern measurement range or combination of ranges there are of course many things to consider. Before one proceeds with subsystem elements several fundamental requirements must be firmly established. The prominent basic questions and design factors are:

3.1.1 What radio frequencies will be employed on the antenna range ?

3.1.2 What size of antennas will be employed in antenna tests ?

3.1.3 What quality of data is required in general and special types of measurements and what are these relationships with respect to paragraphs 3.1.1 and 3.1.2 ?

3.1.4 Quantity of data per se has no useful significance. The ability to acquire quality data in the shortest possible time is important. Since certain portions of the radio frequency spectrum are considerably more active than others one must incorporate a certain amount of duality into the operational system concept in these areas in proportion to present and anticipated future requirements. We shall now proceed to enlarge on these general concepts in terms of what has been considered and done to

accomplish these objectives. In as much as the fundamental requirements are interdependent, the remarks which follow will not necessarily follow the same sequence of basic requirements cited above.

3.2 The distance separation between a given pair of receive and transmit antennas used to conduct a radiation pattern measurement is an important factor. In most instances the measurement of the intensity of the Fraunhofer or far-field zone is the desired objective. This is the zone characterized by the conditions that the various factors contributing to intensity at a given distant point arrive with effectively their initial phase relationships. One finds in the literature that the principal working values for the range (R) between antennas should be:

$$R = D^2/\lambda \ , \qquad R = 2\,D^2/\lambda \ ,$$

$$R = \frac{(D_1 + D_2)^2}{\lambda}, \qquad R = \frac{2(D_1 + D_2)^2}{\lambda}, \quad \text{etc.}$$

where D is the antenna aperture dimension and λ is the wavelength. These are all correct and all qualified in relation to the applicable measurement. See paragraph 9.0 for derivation of equations and related comments. Worthington has stated, "Since there is no single criterion on which to base a minimum range, several reasonable requirements may be satisfied. (1) The measured gain should not be more than 5 percent lower than that which would be obtained under true far-field conditions. With the possibility of a calculated correction this is tolerable in most cases. (2) Relative intensity values should be maintained within 5 percent. (3) The probe antenna must subtend a small enough angle to render good resolution of the pattern. (4) Errors in phase should not exceed $\pi/4$, in order to approximate Fraunhofer conditions." Rather than elaborate extensively here on the appropriate value of (R) the reader is referred to Montgomery, Technique of Microwave Measurements, Volume 11, Radiation Laboratories Series, Chapter 15, R-F Phase and Pattern Measurements by Harvey R. Worthington. It is apparent from the far-field zone equations, that D, D_1, D_2 and λ can vary considerably in an infinite number of combinations with dimensions from a few inches to a great many feet. The ideal universal solution to these requirements is a true space platform at some very large distance (R). Many times this is not feasible, in the practical sense, and one must consider the other methods of measuring "free-space" patterns on a "down-to-earth" effective basis for an extremely very wide variety of conditions.

3.3 Tower Height Considerations

From fundamental criteria, previous experience, a study and/or inspection of various antenna ranges throughout the country, a survey of the literature, maximum versatility throughout the radio frequency spectrum, available land, general weather conditions, economics, power, water, and general logistics, it was obvious that the optimum design for the objectives desired must be in the form of towers separated by appropriate distances. It was also obvious, when considering all factors, that one range leg could not possibly handle the frequency spectrum from 100 Mc to 75 Gc with the usual and unusual sizes of antennas and volume of work required in particular regions of the radio frequency spectrum.

Accordingly a design study was conducted to determine the height and kind of tower which would best serve the maximum number of objectives. The requirements for tower range separation (R) between test platforms have been cited above. The test antennas must be mounted such as to indeed effectively simulate a space platform. Accordingly, the desired height of the antenna above ground level is essential to achieve this desired result. One must design the tower separation, height and the shape of the illuminating antenna beam in such a manner that the terrain between towers does not compromise the accuracy of the measurements and in effect appears ideally not to be there or at least quite tolerable. The illuminating antenna shall hereinafter be referred to as the transmitting antenna and will be referenced to the transmitter tower location whereas the illuminated antenna being evaluated will be referred to as the receiving antenna or test antenna. It should be clearly understood that, the test antenna may serve as the transmitting radiator and the other antenna as a receiving element because the reciprocity law is valid.

One has a reasonably wide choice in selecting the sizes of the "general purpose" transmitting antennas, hence the desired beam shape. The object of this exercise is obviously to choose transmitter antenna beam shapes which do not illuminate the terrain between towers or if they do it should be at a sufficiently low intensity level as not to compromise the accuracy of the measurements. Due consideration of pattern side lobe position and amplitude must be included in the analysis. If these measures are not considered for all situations, serious measurement errors can result from the standing wave field caused by ground reflections between towers. At the other extreme, which is seldom of concern, is the use of extremely narrow transmitter antenna beams in relation to the beam angle subtended by the receiving antenna. For situations in this category one must be certain that the phase and intensity of the transmitter antenna pattern are uniform within the required criterion across that portion of the beam pattern illuminating the receiving antenna. With these factors in mind it is clear that tower separation, height of receiving and transmitting antennas, and transmitter beamwidth are interrelated.

Let us assume that the above conditions have been satisfied and that the receiving antenna is being properly illuminated due to the criteria considered up to this point. One other basic requirement, often overlooked though perhaps obvious, is that the receiving antenna must be mounted on the receiver tower in such a way as to effectively achieve the desired free-space-platform condition. The receiving antenna may have radiation characteristics varying from highly directional to very omnidirectional. In the latter case it is particularly important that the receiver tower and associated apparatus not disturb the criteria for properly illuminating the receiver antenna by the transmitter antenna beam energy being scattered from the tower structure fixtures and instrumentation required thereon. In passing, the transmit antenna also must be properly mounted on the transmit tower so that the origin of the transmitted illuminating signal is of the proper kind from the antenna only. It is essential that transmit antennas with satisfactory front-to-back ratios be employed lest the supporting structure, cables, polarization positioner, etc., be excited and reradiate producing highly undesirable results. Careful tests must be made to ensure the required transmitter wave characteristics at all times and especially so for dynamic measurements in the 20 to 60 db range.

4.0 TRANSMITTING ANTENNA BEAM SHAPES

4.1 We have previously stated that proper illumination of the receiving antenna is essential to measure its radiation pattern characteristics properly. Accordingly, this requires that the entire receiving antenna be illuminated by a wave of uniform intensity and phase at any instant of time. For purposes of illustration let us assume that the apertures of the receiving and transmitting antennas D_1 and D_2 are equal and are the diameter of a cylindrical tube which contains both antennas. The longitudinal axis of this cylinder passes through the center of each antenna. If such a tube of electromagnetic energy of uniform intensity and phase at any cross section face was generated by the transmitter radiator we have formed a cylindrical beam and the energy outside the confines of the cylinder is zero. Such an ideal beam arrangement is not possible and one generally wants the next best approximation to the idealized condition. Although there is a wide variety of beam shapes one might consider, the discussion shall be limited here to the beams which are as near circularly symmetric as possible and particularly that portion of the beam which intercepts the receiving antenna since it must provide, within prescribed limits, the phase and amplitude criteria previously cited. We are now talking generally about "cigar" shaped beams that are analogous to the main beam of this antenna type. We also know that the energy level of the beam outside the confines of the "cigar" shaped envelope is not zero and is quite evident in the form of side lobes at various angles and intensity levels with respect to the main lobe on-axis peak intensity level. In the design of the transmitting antenna it is therefore apparent that the following criteria be met:

4.1.1 That the minimum far-field criteria must be met in accord with the quality of measurement desired.

4.1.2 That the beam generated by transmitting antenna be narrow enough to properly illuminate the receiving antenna without illuminating the terrain between towers or if illuminated that this reflected energy be at a sufficiently low level as not to compromise the quality of the measurements.

4.1.3 That the transmitter beam not be so narrow as to cause variations in intensity and phase within the beam angle subtended by the receiving antenna.

4.1.4 That the transmitter radiation pattern side lobe level and direction of radiation be sufficiently low and/or at an angle such as not to compromise the quality of the desired measurement.

5.0 LAND ACQUISITION AND USE

In September of 1957, New Mexico State University initiated action which subsequently resulted in obtaining approximately two square miles of land designated as that part of sections 23 and 26, Township 23 South, Range 2 East, east of the Dona Ana Bend Colony Boundary, U.S.G.S. Organ Peak Quadrangle, Dona Ana County, State of New Mexico. A photographic enlargement of the map of this land is shown in Fig. 1. The area is approximately two miles east of the NMSU campus proper. The above action, by the University, followed an extensive survey by the Physical Science Laboratory Electromagnetics Group staff of all available and suitable land within a 15-mile radius of the campus proper. Four sites were found technically acceptable for present and future use. One site 10 miles north of the campus was eliminated because of logistic and commercial power problems. Of the three remaining sites, one is located in section 26 and two in section 23. One of the latter two was selected for the following reasons:

(a) Technically acceptable for all requirements.

(b) Site location is approximately two miles east of the campus proper.

(c) Sufficient land was available for the installation without encroachment of other activities which would be of an interference nature.

(d) A well graded state maintained gravel road along the north side of section 23 permits easy access.

(e) A commercial power line serving the AT & T microwave relay tower atop Tortugas mountain follows approximately the east-west dividing line between sections 23 and 26 and is oriented so as not to compromise the

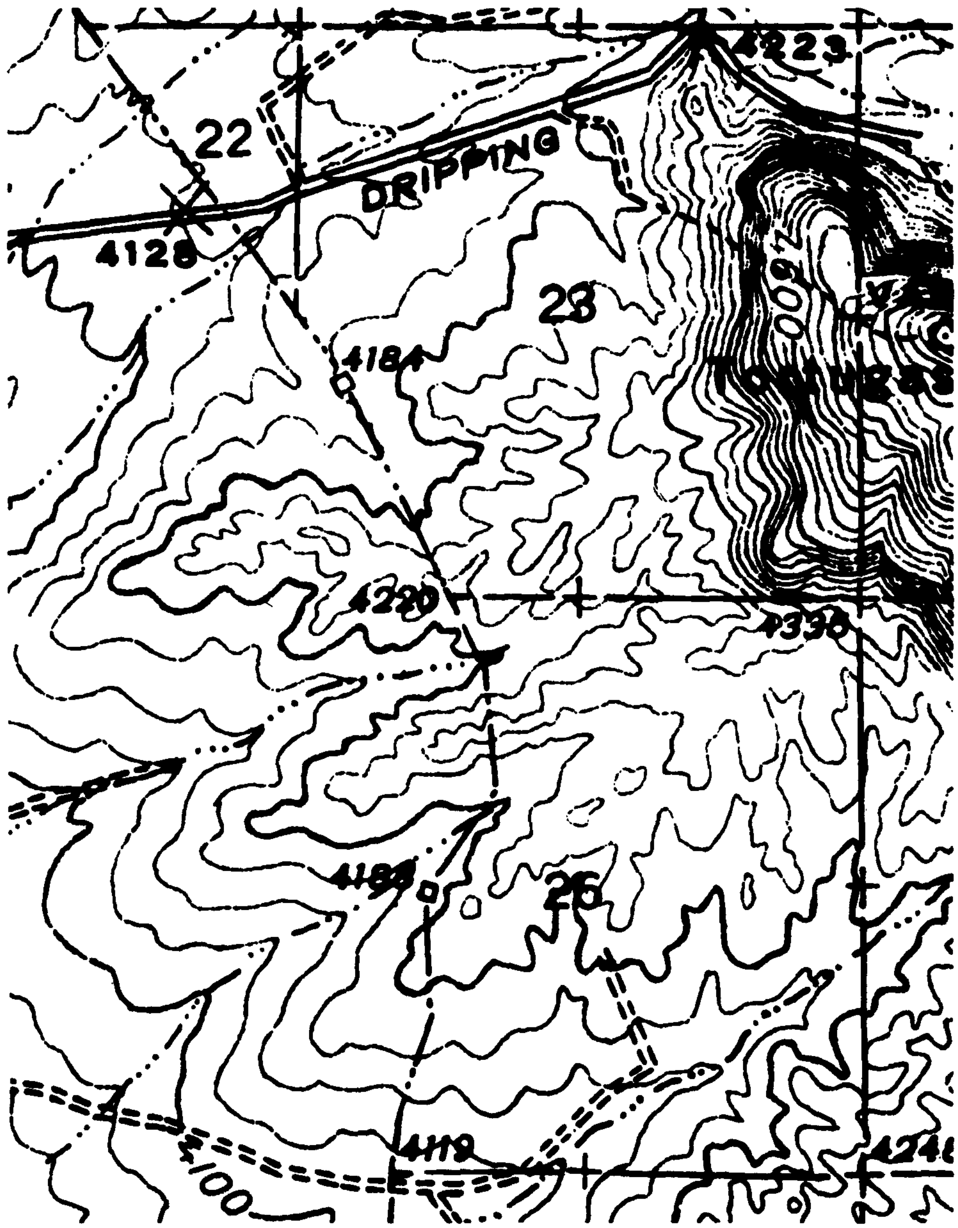
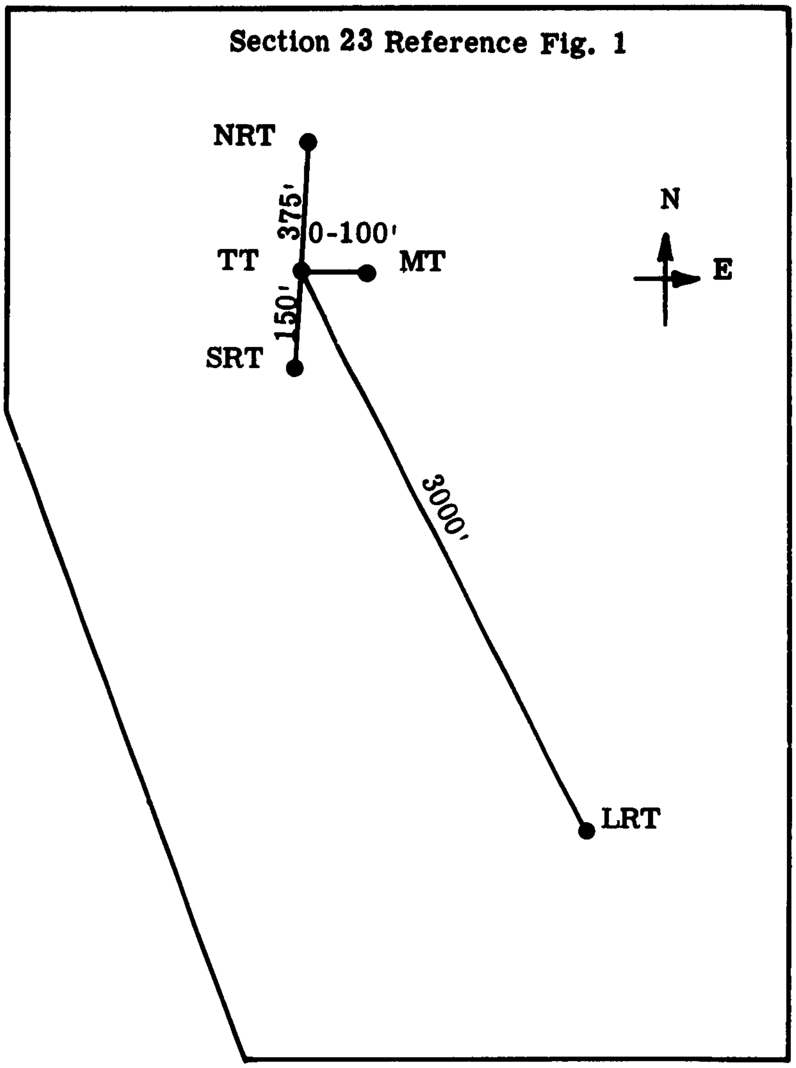


FIG. 1 - Sections 23 and 26, Township 23 south, Range 2 east, east of the Dona Ana Bend Colony Boundary, U. S. G. S. Organ Peak Quadrangle, Dona Ana County, State of New Mexico is the location of the PSL/NMSU Antenna Range. The NMSU campus proper is approximately two miles west and to the left on the road shown at the top of the map.



NRT - NORTH RECEIVER TOWER
TT - TRANSMIT TOWER
SRT - SOUTH RECEIVER TOWER
MT - MODEL RANGE TOWER
LRT - LONG RANGE TOWER

FIG. 2 - GENERAL ARRANGEMENT OF THE FOUR ANTENNA RANGES PSL/NMSU

technical qualities of the antenna range. Greater than fifty KVA is available from this line without modification and is within 600 yards of the desired access point to the main portion of the antenna range and generally situated favorably for future expansion in all directions.

(f) Telephone service was readily available via the power line route direct from the Laboratory PBX board and outside lines.

(g) Adequate space for the addition of a reflectivity measurement range plus ample land for planned expansion in the future is available to interested participants in electromagnetic endeavor.

(h) Soil bearing conditions suitable for buildings and towers.

(i) Easy access to the site for construction phase, (which resulted in a substantial economic saving).

(j) Most suitable area from radio frequency interference considerations.

(k) Maximum protection from cloud burst rain damage.

(l) Site preparation costs virtually nil.

(m) As may be noted in Fig. 1 the crown of Tortugas Mountain is near the center of the eastern north-south boundary line of sections 23 and 26. This portion of the mountain is approximately 4,000 feet from the main range area and is ideal for special problems requiring a propagation path of this order of magnitude. A good quality road constructed by AT & T provides access to the crest of the mountain approximately 700 feet in elevation above the main range proper.

5.0 ANTENNA RANGE BASIC LAYOUT

For reasons previously stated, the antenna range consists of four ranges, i.e.; four propagation paths which may be operated simultaneously. The four ranges are shown by the layout design in Fig. 2.

For purposes of identification and convenience, four of the range sites are designated receiving stations and one as a transmitter station. It should be clearly understood from operational considerations that it makes no difference whether the antennas employed in any tests are transmitting or receiving. In Fig. 2 the designations are the usual modes of operation but may be reversed when warranted by special problem considerations.

The transmitter tower is common to the four legs of the range.

The two primary range legs consist of three towers positioned along a common base line in the north-south direction. The power and telephone lines are brought into the area along the same base line from the south so as to present a minimum cross section to and scatter from the electromagnetic fields associated with measurements.

The north and south receiver towers are 375 and 150 feet north and south of the transmitter tower respectively. The model range propagation path is eastward of the transmitter tower and is variable in length from zero to 100 feet along a two-rail track.

The fourth leg of the antenna range provides for a 3, 000 foot long propagation path from the transmitter tower to a tower on the lower slopes of Tortugas Mountain in a south-easterly direction. It should also be noted, for this leg, that the north and south receiver towers could be used instead of the transmitter tower to change the propagation from a nominal 3, 000 feet to approximately 3, 375 or 2, 850 feet, depending upon the particular nature of the problem, instrumentation requirements, etc.

6.0 SITE PREPARATION

In general very little site preparation was required aside from nominal terrain leveling for construction purposes.

Following the erection of the towers and buildings one area between the transmitter tower and the north receiver building was contoured slightly to minimize ground reflections from one hill slope and to provide uniform storm drainage.

7.0 TOWERS AND BUILDINGS

7.1 Tower Design and Construction

As it has been previously stated, in order to obtain a "space platform" the use of towers of appropriate height and materials is essential to the primary objectives of the range. The Physical Science Laboratory engaged the consultation services of Professor M. D. Creech of the Mechanical Engineering Department for the structural design of the required towers and buildings. From electromagnetic considerations it is desirable to have a minimum amount of metal which would act as scattering surfaces in the tower structure. A study was conducted of the height of tower feasibility vs economics and necessary structural qualities. The towers are designed to withstand 100 mph wind velocity with a safety factor of approximately 1. 5. As will be noted in Figs. 4, 5 and 6, the north and south tower heights to the working platform deck are 70 feet above the tower base, whereas the center tower is 80 feet high to the working deck. The test antenna platforms in the case of

all three towers are 85 feet above the tower base elevation. Lest there be confusion about any difference in heights of test antennas, one must now consider the mechanisms at the top of each tower. The center transmitting tower supports polarization positioners whose axes of rotation are five feet above the platform deck or a total of 85 feet above the base reference level. On each of the receiving towers, the antenna positioner mounted on the top deck is designed to accept a retracting Fiberglas column which, when fully extended, is also 85 feet above the tower base reference elevation. With this arrangement, all test antennas, on these two legs of the antenna range, are 85 feet above the reference elevation and zero elevation angle difference with respect to horizontal. Just below the tower top deck platform there is a small room primarily for personnel during adverse weather conditions and for special instrumentation when required.

The main support for each of the towers is Class-A Southern Yellow Pine, 100% pressure creosoted for structural quality and long life. The basic tower structure is cross braced with structural grade west coast fir lumber and securely bolted to transmit all loads directly to the prime support structure. Personnel access to any level of the towers is accomplished by stairways. Heavy equipment access to the top deck of the tower is accomplished by a hoist mechanism attached to the side of the tower and guided by wooden tracks. Conventional electric drive hoist lift units are used to raise and lower the hoist. Nylon rope, with a tested breaking strength of 6, 000 pounds, has been used on all hoist mechanisms in accordance with the requirement that a minimum amount of metal be used in the towers to keep scattered electromagnetic energy to an absolute minimum and to allow for long time actinic exposure. The live load capacity of each hoist is 1, 200 pounds. The antenna positioners at the tops of the towers will be discussed in detail in another section of this report.

7.2 Instrumentation Building Design and Construction

There are three permanent cinder block buildings associated with the three towers. The two buildings adjacent to the north and south receiver towers are the instrumentation buildings which house the recording instrumentation and controls for the antenna positioning equipment. A large building adjacent to the transmitter tower is divided into two sections, the smallest section houses transmitter instrumentation related to tower antenna functions. The remainder of this building is used for storage of test antennas, mockups, illumination antennas, and standard gain reference antennas. The roof of each building is pre-stressed concrete set in place in modular form and has a load capacity in excess of 50 pounds per square foot. The roofs of ground buildings are water proofed in a conventional manner by applying a tar and gravel mixtu. e. The recorder instrumentation buildings and the transmitter room of the large building are air conditioned with evaporative coolers. Heating is accomplished in the three ground floor buildings and the

three rooms adjacent to the tower top deck by means of electric heaters which are thermostatically controlled. Other forms of heating investigated increase the fire hazard beyond an acceptable level.

The base of each tower support leg is attached to eight yards of concrete for maximum tower stability under normal conditions and maximum safety in high wind conditions. The tower design is such that they would break off at the base prior to over-turning due to wind load. Other design criteria considered tower height versus economics. An additional 10 feet in tower height would add very little more to the precision quality of the range and the additional cost would be considerable.

8.0 ANTENNA POSITIONERS

8.1 North and South Receiver Towers

The design, position, and operation of the test antenna positioner is one of the most critical items of the entire system. It is the largest metallic object in the vicinity of the test antenna, therefore due consideration was given to possible scattering of electromagnetic energy from this assembly. The unit must be capable of supporting anticipated loads and be of adequate electrical and mechanical design to withstand a very wide range of conditions. It is the most active piece of machinery in the antenna range.

The basic azimuth rotator mechanism is the S/A PA-29-2 rotator assembly which rotates the test antenna in azimuth. The number (2) suffix to this model identifies a modification to the standard S/A PA-29 which provides for a larger diameter clearance hole through the vertical axis of the unit to accept an eight-inch diameter Fiberglas tube. The PA-29-2 unit is attached to a supporting unit which is in turn attached to the tower for transferring the load to the tower structure. The base of the support unit also contains one of two keyways and the vertical alignment guide for the Fiberglas column. The second keyway is in the rotating table of the PA-29-2 unit. The total length of the Fiberglas column is 20 feet. The top end of the column can be raised 15 feet, retracted to zero feet, or positioned at any desired intermediate point above the azimuth turntable. The compressive load on the column is supported at the base of the column by an assembly which permits column rotation without rotation of the support assembly. The column support assembly is raised and lowered by a nylon rope and pulley arrangement having six to one mechanical advantage. The rope is attached to a winch and associated reversible drive motor assembly. The electric drive winch assembly is placed at the base of the tower to keep this large metallic unit as far away from the test antenna as possible. Up, down and override stop controls on column vertical motion are provided in the immediate vicinity of the rotator and at the recorder console in the ground level north and south receiver station buildings.

Two sets of limit switches are provided for column motion. One set limits travel at the extreme positions and is fixed; the other set can be manually set for any two intermediate positions applicable to the measurement problem at hand.

Azimuth torque is transmitted to the column by the keyway in the azimuth turntable of the PA-29-2 positioner. The maximum allowable compressive load on the PA-29-2 turntable is 6,000 pounds. The rotator has a greater capacity, however, the 6,000 pound concentrated load is the maximum allowable to be transmitted to the top deck of the platform at the rotator position which is in turn transmitted to the support poles. The vast majority of the test antennas weigh less than 1,000 pounds and most of these are 200 ± 100 pounds.

Since the test antennas are attached to the upper part of the Fiberglas column and positioned 10 to 20 feet above the rotator herein lies the critical load problem. The mechanical properties of the column are such that with the column fully extended to 15 feet, the maximum safe deflection from vertical must not exceed 10 inches. Maximum design compressive load on the column under the worst condition of deflection is 1,200 pounds. In normal operations to date and under wind conditions of 30 to 40 knots, the column deflection for most antennas having large wind load surfaces is in the order of one inch. The antenna range area is susceptible to higher wind gusts and occasional whirl winds of severe velocity, hence the design must allow for protection of test antennas against loss or damage.

The Fiberglas column was primarily selected on the basis of electrical properties and fortunately one of the best choices is a type normally designed for high pressure fluid transmission systems and produced in such quantity that the price was considerably less than that of any comparable column especially fabricated for similar antenna support requirements.

For the purpose of attaching antennas to the top of the column a Fiberglas pipe flange was permanently attached with an epoxy bonding agent. A wide variety of antenna mounts may be attached to this flange. The center of the column is hollow to accept coaxial or waveguide transmission lines as required for the particular problem. At the base of the column, provisions are made for rotary joints to prevent transmission line twist due to column rotation.

8.2 Polarization Positioners on the Transmitter Tower

There are three antenna polarization positioners on the transmitter tower. Two of these are heavy duty S/A PP-23 units which are used in conjunction with operations on the north and south receiver towers. The third unit is lighter duty S/A PP-13 unit used in conjunction with the model range. This positioner is in a fixed position and at the same height as the upper portion of

the model rotator Fiberglas support assembly. The PP-23 units are mounted on small four-wheel carts which ride on and may be locked securely to rails on the top deck of the transmitter tower.

To facilitate easy, rapid and safe mounting of illuminating antennas, hoists are provided on the north and south sides of the transmitter tower. These hoists have been fitted with rails matched to those mentioned above. When the hoist is raised to maximum height, the hoist and platform rails are match-aligned and lock in place. The cart-mounted PP-23 is rolled onto the hoist and lowered to ground level for mounting of illumination antennas ranging from a few pounds to several hundred and dimensions of a few inches to many feet in diameter and/or axial length.

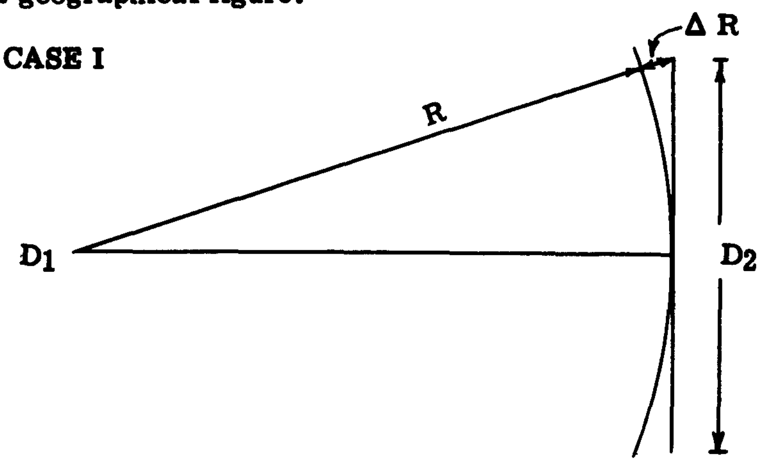
Each PP-23 and 13 polarization positioner is used for mounting the illumination antenna employed on a particular range leg in conjunction with the test antenna at a particular receiver tower station. These units are capable of rotating the illumination antenna in excess of 360° or may be stopped automatically by setting the limit switches to any increment within this range.

Typical installations of transmitter antennas are shown later in the report. The 360° rotation of the polarization positioner units permit rapid evaluation of the axial ratio of an illumination antenna when the signal is sampled by a linear antenna mounted on the receiver station column. The pattern recorder may be synchronized with the angular rotation of the PP units and the axial ratio plotted for 0° to 360° in twenty seconds. If the axial ratio of a test antenna in some specified direction is required it is readily obtained by employing a linearly polarized antenna on the polarization positioner which is rotated 360° and the signal recorded vs angular position. When recording linearly polarized patterns of a test antenna, i.e., the $E\phi$ and $E\theta$ components, the polarization positioner limit switches are set for a 90° change in position. This permits rapid sequence of pattern measurements. The polarization positioners are remotely controlled from the pattern recorder console. Angular position of the PP units are also displayed on synchro read-out units with a 1:1 or 36:1 ratio. Each of the polarization positioners have ± 10° elevation and ± 5° azimuth manual adjustment for initial alignment of the beam axis toward the test antenna. Physical Science Laboratory has also modified the PP-23 unit mounts for + 30° to -10° manual elevation positioning for special low frequency problems where the illumination antenna has an unusually wide beam and may be elevated to an appropriate angle to reduce the standing wave field to the tolerance required for the measurement. When this procedure becomes necessary, in cases below the low frequency design limit of the range, it is recognized that differential levels of $E\phi$ and $E\theta$ of the transmitting antenna as a function of antenna orientation must be accounted for when the beam is not circularly symmetric.

9.0 RANGE SEPARATION DISTANCES BETWEEN RECEIVING AND TRANSMITTING ANTENNAS

Two derivations are presented which are often mentioned in the literature and are used as an approximation in some applications. These examples are by no means all of the criteria for arriving at the proper range separation for certain problems. If the required accuracy is to be obtained, the proper interpretation must apply rather than the equation that can yield the lowest geographical figure.

CASE I



D_1 is a point source isotropic radiator

D_2 is aperture of other radiator

ΔR is the allowable deviation in phase from a plane wave front as compared to the spherical wave front at range R

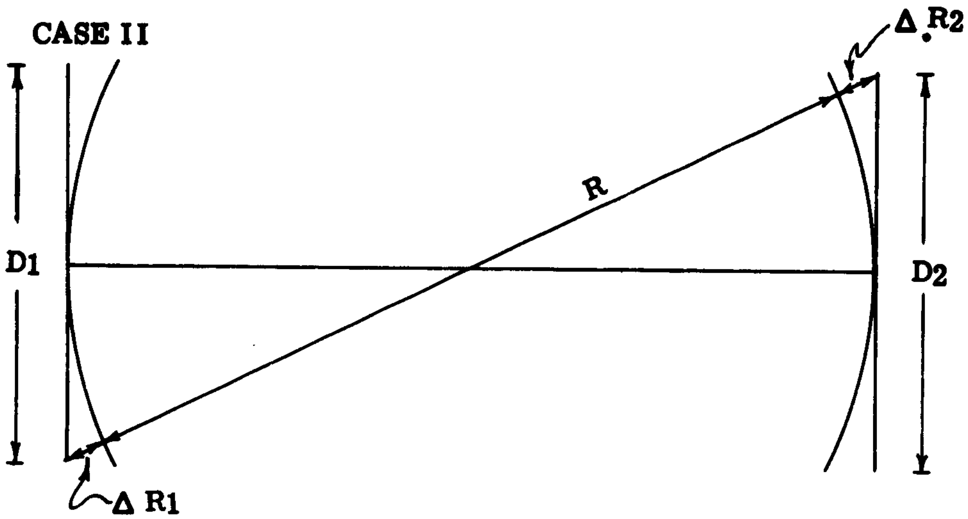
$\Delta R \ll R$, accordingly; $R^2 + (D_2/2)^2 = (R + \Delta R)^2$

Hence $R = (D_2)^2 / 8\,\Delta R$

If ΔR allowable is $\lambda/8$ then $R = D_2^2/\lambda$

If ΔR allowable is $\lambda/16$ then $R = 2\,D_2^2/\lambda$, etc.

Comment: In practice $D_1 \neq 0$



In the literature one finds the equation $R = (D_1 + D_2)^2/\lambda$ which is useful, provided that appropriate interpretation is utilized and the difference between Case II and Case I is apparent. The argument is simplified by assuming that:

$$D_1 = D_2$$

$$\therefore \quad D_1/2 = D_2/2$$

hence $D_1/2 + D_2/2 = (D_1 + D_2)/2$

also $\Delta R_1 = \Delta R_2$

hence $\Delta R_1 + \Delta R_2 = \Delta R_T$

where ΔR_T = total allowable deviation

and $\Delta R_T = \ll R$

The calculations follow as in Case I

$$R^2 + \left(\frac{D1 + D2}{2}\right)^2 = (R + \Delta R_r)^2$$

$$R = \frac{(D1 + D2)^2}{8\,\Delta R_r}$$

If ΔR_T allowable is $\lambda/8$ then $R = \frac{(D1 + D2)^2}{\lambda}$

If ΔR_T allowable is $\lambda/16$ then $R = \frac{2\,(D1 + D2)^2}{\lambda}$, etc.

It is readily apparent that the result is obtained by considering, in this case, a double ΔR, $R_1 = R_2$ and double half-aperatures $(D_1/2 = D_2/2)$ and proceed as in Case I. By inspection if $D_1 = 0$, hence $R_1 = 0$, the above solution for R reduces to that of Case I.

10.0 RADIATION PATTERN MEASUREMENT PROCEDURE

As a part of designing an antenna range for a wide variety of applications involving many people it was necessary to establish a uniform procedure for internal use as well as one which is understood or could be easily understood by other persons requiring detailed knowledge of the data.

In order to achieve a suitable answer to this important problem a report was compiled in July of 1961 which contains most of the "how and why" information required for pattern measurements. The first part of the report is devoted to this laboratory's method of obtaining uniform procedure and includes various factors applicable to the Physical Science Laboratory, New Mexico State University antenna range. Part two of the report, courtesy of Scientific-Atlanta Incorporated, is an excellent digest on "Antenna Measurements", 1 February 1959, by J. S. Hollis of that company. Part three has been subsequently added for general information purposes and is identified as ASTIA Document No. 102-61 "IRIG Standard Coordinate System and Data Format for Antenna Patterns."

The information contained in this composite document, particularly with the indicated bibliographies, should fully inform all concerned with the desired information. A considerable effort has been directed toward recording and presenting data in a conventional and the most widely accepted procedure.

11.0 ANTENNA RADIATION PATTERN FORMAT

As part of the overall antenna range objective it is essential to have recorded accurate original data transmitted through various channels and included in technical reports without intervening processes. This policy provides the desired data quality to all concerned. It is also more economical since any intermediate steps are eliminated. A survey of many procedures including those previously used at this laboratory revealed that a new approach was required that would satisfy all of the problems simultaneously. Only the future will determine the degree of success, but at least after one year's operation most of the users and recipients of the results were satisfied all of the time. One of the most useful formats is shown on the two pages following this description. It was arrived at through many discussions with users, analysis of paper, inks, reproducibility, compatibility with instrumentation and ease of reduction to power contour plots when required. When printed, both pages of the format are joined at the center and machine folded back to back. The latter is necessary to prevent the recording page surface from touching the recording pen when the paper is placed on or removed from the recorder turntable. All necessary data is entered on the data sheet at the time it is recorded. A

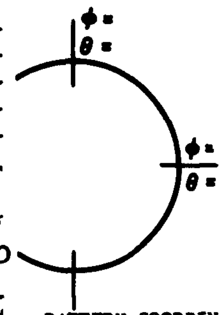
typist may later type the required data from the work sheet in the appropriate blanks of the recorded pattern. Following this step the sheets are cut apart for processing as required. Each page has the same pattern sequence number for future reference when desired. Each polarization kind is pen coded when the recording is made.

Proprietary Information

PHYSICAL SCIENCE LABORATORY

SECURITY CLASSIFICATION ____________

1. PSL ANTENNA RANGE - DATA NOTATION - DO NOT WRITE ON PATTERNS
2. RANGE USED (CHECK ONE)
   NORTH, SOUTH, MODEL, LONG, ROOF
3. DATE ____________ FUND NO. ____________
4. OPERATORS ____________
5. ANTENNA & CONFIGURATION ____________
6. FREQUENCY
7. WIND VELOCITY ________ TEMPERATURE ______ °F
8. SKY ________ OTHER ________
9. MOCKUP CENTERLINE ABOVE PLATFORM ______ FT
10. TRANSMIT OR RECEIVE ANTENNA USED OPPOSITE TO ITEM 5 ____________
11. ELEVATION OF ITEM 10 ______ ° ABOVE HORIZONTAL
12. DYNAMIC RANGE OF RECORDER
    ________ db = ________ db PER CIRCLE DIVISION
13. POLARIZATION
    (CHECK ONE & NOTE PEN CODE TO BE USED)



PATTERN COORDINATES

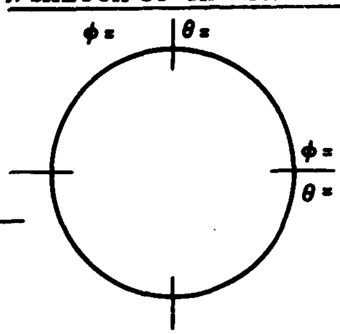
PSL Nº 21979

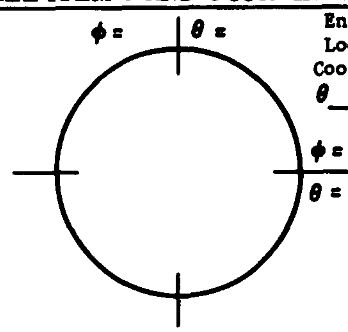
POLARIZATION	PEN CODE	REMARKS - USE BACK OF SHEET IF NECESSARY
☐ GAIN REF.	— — — —	
☐ E θ	————	
☐ E ϕ	— — —	
☐ R C	- - - -	
☐ L C	— - — -	
☐ OTHER AS NOTED		

COMPLETE ONCE FOR EACH SET OF PATTERNS.

A SKETCH OF THE ORIENTATION OF ALL ITEM 5 AND COORDINATES

Side view
Looking into
Coordinates
θ ____ ϕ ____





End view
Looking into
Coordinates
θ ____ ϕ ____

ALSO SHOW: TYPE & POSITION OF FEED CABLE
TYPE, LENGTH & POSITION OF CABLE HARNESS
DESIGNATE REFERENCE ANTENNA

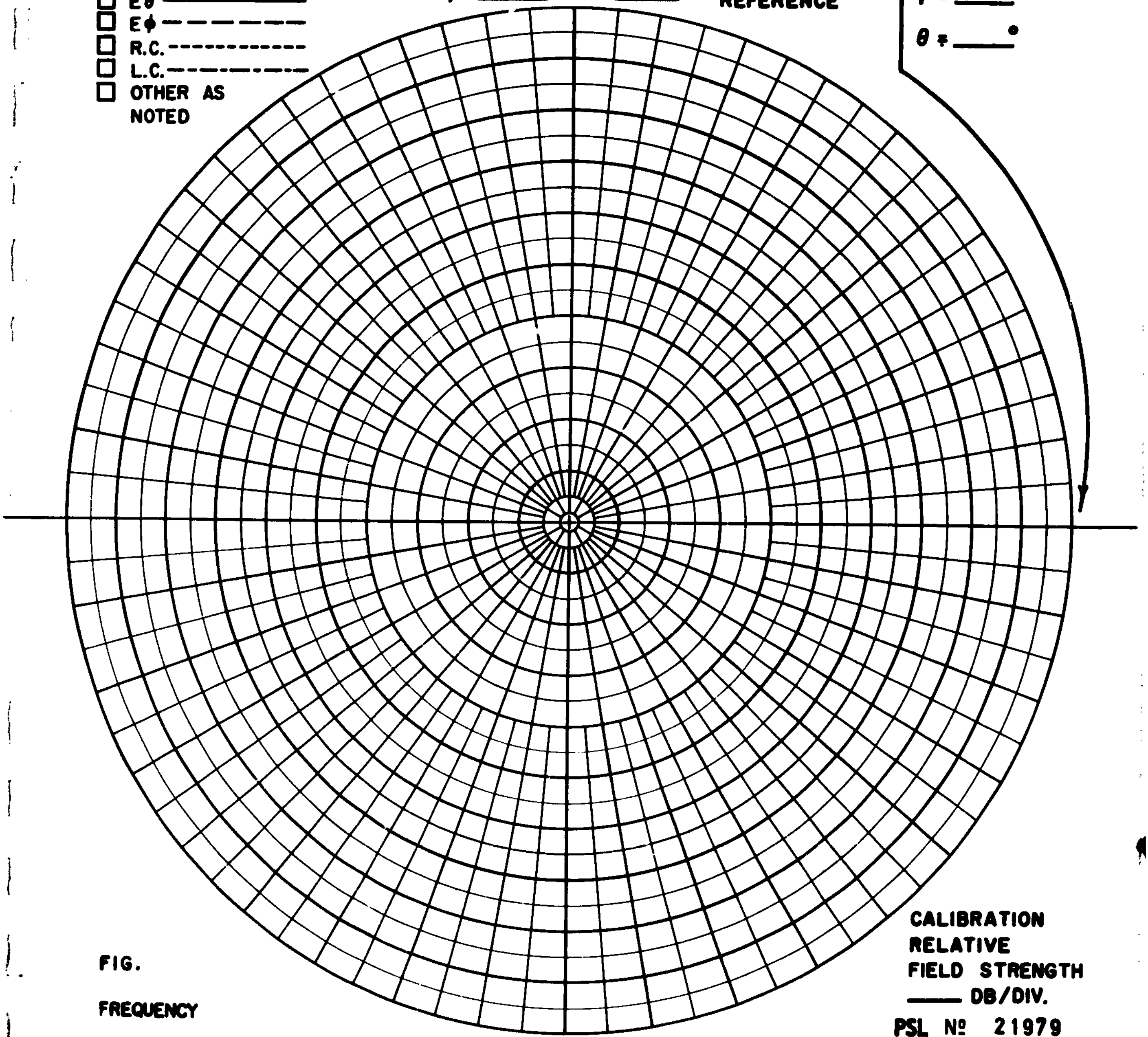
POLARIZATION

- ☐ GAIN REF -- -- --
- ☐ Eθ ————————
- ☐ Eϕ — — — — — —
- ☐ R.C. ------------
- ☐ L.C. —-—-—-—-—
- ☐ OTHER AS NOTED

ϕ = ____ ° θ = ____ ° COORDINATE REFERENCE

ϕ = ____ °

θ = ____ °



CALIBRATION
RELATIVE
FIELD STRENGTH
____ DB/DIV.

PSL № 21979

FIG.

FREQUENCY

ANTENNA

REMARKS

12.0 EQUIPMENT

The following two lists of principal equipment is used by the electro-magnetics group in support of various contractural endeavor.

The first list is of equipment used primarily at the antenna range and the second for equipment used primarily in laboratory tests. The latter is included for general information purposes.

12.1 Manufacturer's Code

MANUFACTURER	CODE
ALLEN D. CARDWELL MFG.	AC
ALLEN B. DUMONT	D
ALLIED RADIO	AR
BIRD ELECTRONICS RESEARCH	BE
BOONTON RADIO	B
CENTRAL SCIENTIFIC	C
DEMORAY-BONARDI	DB
DON-LAN ELECTRONICS	DL
DRESSEN-BURNS ELECTRONICS CORP	DR
ELECTRONIC DESIGN, INC.	ED
ESTERLINE-ANGUS CO.	EA
GENERAL RADIO CO.	GR
GERBER SCIENTIFIC INSTRUMENTS	G
HEWLETT PACKARD	HP
HICKOCK ELECTRICAL INSTRU. CO.	H
INTERNATIONAL CRYSTAL MFG. CO.	IC
KINNEY VACUUM DIV.	K
LECTRONICS RESEARCH CO.	LR
MARYLAND ELECTRONICS MFG.	ME
MAURY ASSOCIATES	MA
MEASUREMENTS CORP.	MC
MICROLAB	M
POLARAD ELECTRONICS	PE
POLYTECHNIC RES. & DEV.	PRD
ROLLIN COMPANY	R
SCIENTIFIC-ATLANTA	SA
SIERRA ELECTRONICS	SE
SIMPSON ELECTRIC CO.	SI
STODDART AIRCRAFT RADIO	S
TEKTRONIX	T
TRIPLETT ELECTRIC CO.	TE
W. M. WELCH SCIENTIFIC CO.	WS
WEINSCHEL ENGINEERING	W
T. W. TORNGREN	TG

ANTENNA RANGE PRIMARY EQUIPMENT (1 April 1963)

ITEM	DESCRIPTION	CODE	MODEL NO.	AMOUNT
1	Adapter, Coax to Waveguide	HP	G 281 A	2
2	Adapter, Coax to Waveguide	HP	J 281 A	2
3	Adapter, Coax to Waveguide	SA	CA1-0.9	2
4	Adapter, Coax to Waveguide	SA	CA1-1.1	2
5	Adapter, Coax to Waveguide	SA	CA1-1.7	2
6	Adapter, Coax to Waveguide	SA	CA1-2.6	2
7	Adapter, Coax to Waveguide	SA	CA1-3.9	2
8	Adapter, Coax to Waveguide	SA	CA1-5.8	3
9	Adapter, Coax to Waveguide	SA	CA1-8.2	2
10	Amplifier, Unit IF	GR	1216-A	2
11	Amplifier, Standing Wave	PRD	277-B	2
12	Antenna, Dipole	S	91865-2	1
12a	Antenna, Dipole	S	90833-2	1
13	Antenna, Dipole	S	91870-2	2
14	Antenna, Feed	SA	TAF-2.6	1
15	Antenna, Feed	SA	TAF-3.9	1
16	Antenna, Feed	SA	TAF-5.8	1
17	Antenna, Feed	SA	TAF-8.2	1
18	Antenna, Feed Various	PSL	400-2600 Mc	15
19	Antenna, Helix 36 Mc RC	PSL		1
20	Antenna, Helix 82 Mc RC	PSL		1
21	Antenna, Helix 128 Mc RC & LC	PSL		1 of ea.
22	Antenna, Helix 150 Mc RC & LC	PSL		1 of ea.
23	Antenna, Helix 230 Mc RC	PSL		1
24	Antenna, Helix 250 Mc (Tri)	PSL		1
25	Antenna, Helix 305 Mc RC	PSL		1
26	Antenna, Helix 425 Mc RC & LC	PSL		1 of ea.
27	Antenna, Helix 600 Mc LC	PSL		1
28	Antenna, Helix 882 Mc LC	PSL		1
29	Antenna, Yagi	AP	150 Mc	1
30	Antenna, Yagi	AP	400 Mc	1
31	Antenna, Yagi	AP	YG-1000	1
32	Antenna, Yagi	AP	136 Mc	1
33	Antenna, Yagi	AP	123 Mc	1
34	Antenna, Yagi	L	FMY 8	1
35	Antenna, Yagi	L	YL10-8	1
36	Antenna, Yagi	TACO	Y 54	1
37	Antenna, Yagi	TACO	Y104-4	1
38	Antenna, Yagi	TACO	Y-101-5	1

ITEM	DESCRIPTION	CODE	MODEL NO.	AMOUNT
39	Antenna, Yagi	TACO	Y-103-K	1
40	Antenna, Yagi	TACO	Y-103-M	1
41	Antenna, Yagi	TACO	Y-103-N	1
42	Antenna, Yagi	TACO	Y-103-P	1
43	Attenuator, Turret	S	90518-9	2
44	Attenuator, Turret	S	90518-13	2
45	Attenuator, Turret	S	90506-9	2
46	Attenuator, Adjustable	GR	874-GA	4
47	Attenuator, Variable	HP	G382-A	1
48	Attenuator, Variable	HP	J 382-A	1
49	Attenuator, Fixed	M	AB-06N	7
50	Attenuator, Fixed	M	AC-06N	7
51	Detector, Crystal	HP	420A-95B	3
	Filter, Low Pass		LA01N	1
52	Filter, Low Pass	M	LA02N	1
53	Filter, Low Pass	M	LA03N	1
54	Filter, Low Pass	M	LA04N	1
55	Filter, Low Pass	M	LA07N	1
56	Filter, Low Pass	M	LA15N	1
57	Filter, Low Pass	M	LA20N	1
58	Filter, Low Pass	M	LA30N	1
59	Filter, Low Pass	M	LA40N	2
60	Filter, Low Pass	M	LA50N	1
61	Filter, Low Pass	M	LA60N	2
62	Filter, Low Pass	M	LA70N	1
63	Filter, Low Pass	M	LA80N	1
64	Filter, Low Pass	M	LA90N	1
65	Filter, Low Pass	M	LA100N	1
66	Flange, Mounting (Horn)	SA	MF-0.9	2
67	Flange	SA	MF-1.1	2
68	Flange	SA	MF-1.7	2
69	Flange	SA	MF-2.6	2
70	Flange	SA	MF-3.9	2
71	Flange	SA	MF-5.8	2
72	Flange	SA	MF-8.2	2
	Meter, Admittance	GR	1602-B	2
73	Meter, Frequency	HP	536-A	1
74	Meter, Frequency	PRD	504	3
75	Meter, Volt-ohm	SI	270	1
76	Meter, Volt-ohm	TE	310	5
77	Meter, Volt-ohm	TE	630-NA	1
78	Mixer, Crystal	SA	CM-1A	2
79	Oscillator, Unit	GR	1208-B	2
80	Oscillator, Unit	GR	1209-B	2

ITEM	DESCRIPTION	CODE	MODEL NO.	AMOUNT
81	Oscillator, Unit	GR	1215-B	2
82	Oscillator, Unit	GR	1218-A	1
83	Oscillator, Unit	GR	1361-A	2
84	Oscillator, Unit	SA	RFO-1	1
85	Oscillator, Unit	SA	RFO-2	1
86	Oscillator, Unit	SA	RFO-3.6	1
87	Oscillator, Unit	SA	RFO-7	1
88	Oscillator, Unit	SA	RFO-8.5	1
89	Parabolic Reflector	TG	120 inch	1
90	Parabolic Reflector	TG	72 inch	1
91	Parabolic Reflector	TG	60 inch	1
92	Parabolic Reflector	TG	48 inch	1
93	Position Indicator (Azimuth)	SA	IU-3	4
94	Position Indicator (Elevation)	SA	IU-3	3
95	Position Indicator (Polarization)	SA	IU-3	3
96	Positioner Control Unit	SA	PC-2-33	3
97	Positioner Control Unit(Az)	SA	PC-1	1
98	Positioner, Azimuth	SA	PA-29-2	2
99	Positioner, Azimuth	SA	PA-29 BL	1
	Positioner, Azimuth	SA	PA-15C	1
100	Positioner, Polarization	SA	PP-13	1
101	Positioner, Polarization	SA	PP-23	2
102	Power Divider, Reactive	M	D3-2TT	2
103	Power Divider, Reactive	M	D3-4TT	2
104	Receiver	SA	402C	2
105	Receiver	SA	402CP	2
106	Recorder, Linear (Head only)	SA	APR-25	1
107	Recorder, Polar	SA	APR-35-S136	4
108	Recorder, Pen Programmer	SA	RPP-1	3
109	Rotary Joint High Speed Coax	SA	RJ-2	5
110	Signal Source, Remote	SA	SS-21	2
111	Tripod and Feed Support	SA		3
112	Tower, Model	SA	MT-1	1
113	Tower, Model Extension	SA	MTE	1
114	Horn, Standard Gain	SA	SGH-0.9	2
115	Horn, Standard Gain	SA	SGH-1.1	2
116	Horn, Standard Gain	SA	SGH-1.7	2
117	Horn, Standard Gain	SA	SGH-2.6	2
118	Horn, Standard Gain	SA	SGH-3.9	2
119	Horn, Standard Gain	SA	SGH-5.8	2
120	Horn, Standard Gain	SA	SGH-7.0	2
121	Horn, Standard Gain	SA	SGH-8.2	2

ANTENNA SECTION LABORATORY EQUIPMENT

ITEM	CODE	MODEL NO.	AMOUNT
Admittance Meter	GR	1602-B	7
Air Line, Rigid	GR	874-L30	11
Air Line, Rigid	GR	874-L20	13
Air Line, Rigid	GR	874-L10	12
Air Line, Adjustable	GR	874-LK20	24
Stub, Adjustable	GR	874-D20	1
Air Line, Adjustable	GR	874-LT	1
Amplifier, Standing Wave	GR	277-B	1
Amplifier, Unit, I. F.	GR	1216-A	11
Attenuator, Variable	GR	874	1
Attenuator, Adjustable	GR	874-GA	4
Attenuator, Adjustable	PRD	1156	1
Attenuator, Variable	PRD	195-A	1
Attenuator	S	90506-9	1
Attenuator	PRD	195	1
Attenuator	PRD	159-A	1
Attenuator, Fixed	GR	874-G10	24
Attenuator, Fixed	GR	874-G20	7
Attenuator, Fixed	S	90511-10db	1
3 db Coupling Attenuator	--	-----	1
Attenuator, Fixed	GR	874-G6	1
Coupler, Dual Directional	HP	167-D	1
Coupling Capacitor	GR	874-K	1
Coupler, Waveguide Directional	HP	752-A	1
Coupler, Waveguide Directional, Multihole	--	----	1
Coupler, Dual Direction (20 db)	HP	765-D	1
Coupler, Micromatch Unit	--	MM57654	2
Coupler, Cross Guide Directional	HP	J750D	1
Coupler, Multihole Directional	HP	J752C	1
Coupler, Directional	HP	764D	1
Coupler, Directional	HP	NAS5-352	1
Mount, Crystal Detector	FXR	N210B	1
Detector, Assembly	GR	DNT-1	2
Detector, Mount	HP	440-A	1
Detector, Standing Wave	PRD	219	1
Detector, Crystal	HP	420A	3
Detector, Mount	HP	485B	1
Detector, Mount	HP	440A	1
Detector, Mount	FXR	210A	2
Detector	GR	874-MR	1
Detector, Barretter Mount	HP	485-D	1

ITEM	CODE	MODEL NO.	AMOUNT
Detector, Untuned Probe	HP	444A	1
Filter, Low Pass	M	LC-01N	1
Filter, Low Pass	M	LA-30N	1
Filter, Low Pass	M	LA-20N	1
Filter, Band Pass	ME	----	1
Filter, Low Pass	GR	874-F185	7
Filter, Low Pass	GR	874-F800	2
Filter, Low Pass	MA	LP-750-C43	1
Filter, Low Pass	MA	LP-875-C43	1
Filter, Low Pass	MA	LP-1000-C43	1
Filter, Low Pass	MA	LP-500-C43	1
Filter, Low Pass	MA	LP-250-C43	2
Filter, Low Pass	GR	874-F-1000	1
Filter, Low Pass	GR	874-F-500	3
Head Phones	--	131 'CW'	3
Head Phones	--	BA-200	9
Head Phones	--	10796	1
H-Plane T	PRD	457	3
E-Plane T	PRD	456	3
H-Plane Bent	PRD	455	3
Termination, Low Power (50 ohm Load)	M	TA 5 MT	4
Termination	W	535-MN	1
Termination, Low Power	M	TA 5 MN	2
Termination, Low Power	M	TA 5 MB	2
Termination, 100 ohm	GR	874-W 100	5
Termination, 50 ohm	GR	874-WM	42
Termination, S. C.	GR	874-WN3	1
Termination, High Power	--	X912A10CA	1
Load, 100 Watt	S. C.	160-100 FN	1
Meter, Admittance	GR	1602-B	2
Meter, Microwave Power	PE	P-3	1
Meter, MC and Griddip	MC	59	3
Meter, VSWR	PRD	277B	1
Wattmeter	R	60	1
Milliammeter	EA	39-D	1
Oscillogram Scanner	G	S-2	1
Oscilloscope	T	502	1
Oscillograph	D	208-B	1
Meter, Output	GR	583-A	1
Oscilloscope	T	513-D	1
Meter, Power	HP	430-C	1
Meter, Reflection Coefficient	S. E.	136-B	1
Meter, RX	B	250-A	3

ITEM	CODE	MODEL NO.	AMOUNT
Meter, Frequency	PRD	504	2
Meter, Frequency	AC	TS-175/U	11
Meter, Frequency	GR	720A	1
Meter, Frequency	GR	891	1
Meter, Frequency	H	530A	1
Crystal Mixer	SA	M-1.8	1
Crystal Mixer	GR	874-MRL	1
Crystal Mixer	SA	M-8.2	1
Crystal Mixer	SA	M-26	1
Crystal Mixer	SA	M-3.9	1
Crystal Mixer	SA	M-5.8	1
Crystal Mixer	SA	CM-1	3
Microammeter	SI	374	1
Milliammeter	--	630-A	1
Milliammeter	TE	310	1
Voltmeter	--	300A	1
Voltohmmeter	ED	----	1
Tester, Tube	H	539-C	1
Vacuum Gauge	K	TD-1	1
Short, Adjustable	M	SO-6MT	1
Coil, High Frequency	C	80730	1
Freezing Trap	C	94002	1
Probe, Broad Band	HP	442-A	1
Plug In Element	SE	180-470	1
Plug In Element	SE	180-1000	1
Indicator, Standing Wave	HP	415	6
Power Monitor, Bi-Directional	SE	----	1
Plug In Element	SE	180-470	1
Tuner, Twin Stub	DL	S-100	2
Frequency, Converter	HP	525-B	1
Electronic Counter	HP	524-C	1
Susceptance Unit, Variable	PRD	3302-L	1
Detector Mount	HP	440-A	1
Carriage	HP	809-B	2
Slide Screw Tuner	HP	J870-A	1
Receiver	LR	AN/APR-5A	2
Probe, Broad Band	HP	442-B	1
Coil, High Frequency	C	80730	1
Twist Section	DB	DBJ-274	2
Plug In Element	SE	180-1000	1
Rotator No. 92TX299	AR	U-98	1
Thermistor Mount	HP	477B	1
Indicator, Standing Wave	PRD	219	1
Shaded Pole Blower	LR	160CFM	1

ITEM	CODE	MODEL NO.	AMOUNT
Vacuum Gauge	WS	1451K, type B	1
Rack, Relay	BE	CR1772	2
Barretter Mount	--	184	1
Crystal Holder	PRD	613-M	1
Selective Amplifier	--	----	1
Motor Speed Control Chassis	--	----	1
Model Rotating Mechanism	--	----	1
Servo-Amplifier	--	----	1
Receiver	--	APR-4	1
Extractor, Multiple Outlet	--	538-A	1
Equivalent Line Section	SE	164-LS	1
Short Circuit	GR	874-WN3	2
Radiating Line	GR	874-LR	1
Coax Tee	GR	874-T	1
Slot Section	HP	X810B	1
Transmitter, Telemetry	--	AN/DKT-7(SN-2)	1
Powerstat	--	116	1
Crank-Up Tower	--	M 90-A	1
Crystal & Bolometer Mount	PRD	613-MSL	2
Oscillator, Crystal Pkg. (136.5 & 166.5 Mc)	IC	----	1
Oscillator, Unit	GR	1214-A	4
Oscillator, Unit	GR	1208-B	14
Oscillator, Unit	GR	1209-B	6
Oscillator, Unit	GR	1215-B	7
Oscillator, Transfer	HP	540B	1
Oscillator, Unit	GR	1218-A	4
Oscillator, Unit	GR	1209-A	2
Oscillator, Klystron	GR	1220-A	2
Oscillator, Audio Frequency	HP	200-C	1
Oscillator, Audio Frequency	HP	200LR	1
Oscillator, Audio Frequency	HP	200IR	1
Oscillator, UHF Power-Wide Band	--	M-1141-AB	1
Power Supply, d-c	DR	22-109	1
Power Monitor, Bi-Directional	SE	164-FMN	1
Power Supply	GR	1201-B	8
Power Supply	GR	1201-A	1
Power Supply, Klystron	GR	1220-A	1
Power Supply, Klystron	GR	1203-B	8
Power Supply	GR	1203-A	1
Antenna Recording Equipment	--	----	1
Recorder	--	----	1
59952 Polar Recorder	--	----	1
Polar Power Level Recorder	--	----	1

ITEM	CODE	MODEL NO.	AMOUNT
Rectifier, Mixer	GR	874-MR	9
Signal Generator N383-4609 3V	--	341:TRAA	1
Signal Generator	NUCLEAR ELECT.	----	1
Signal Generator	HP	618-B	3
Signal Generator	HP	616-A	2
Signal Generator	HP	616-B	1
Signal Generator	PAPAL BROS.	TS-13-AP	1
Signal Generator	KELLEX CORP.	SCI-222-A	1
Signal Generator	HP	608D	1
Signal Generator	HP	700A	1
Signal Generator	--	LP-3	1
Signal Generator	--	L&G	1
Slotted Line	HP	805-A	2
Slotted Line	GR	874-LBA	1
Slotted Section	HP	806-B	5
Slotted Section	HP	J810-B	1
Slotted Line	GR	874-DA	1
Carriage, Slotted Line	HP	809-B	2
Standard Gain Horn (20 db)	DB	DBJ-520	1
Transformer	--	3060	1
Transformer	-	TYPE H	1
Transformer	--	30808	2
Transformer	--	TYPE 116	3
Transformer, Variable Powerstat	--	----	1
Adapter, Waveguide to Coax	PRD	356-A	5
Waveguide Phase Shifter	HP	X885A	1
Waveguide Termination	PRD	121-A	2

13.0 GENERAL REMARKS

The photographs and descriptions which follow are intended to provide the reader with an accurate functional concept of the antenna range and arrangement of the various parts thereof.

FIG. 3 - AN OVERALL VIEW OF THE PSL/NMSU ANTENNA RADIATION PATTERN RANGE COMPLEX

The main antenna ranges are located approximately three miles from the Physical Science Laboratory on the New Mexico State University Campus on two square miles of land acquired for electromagnetic endeavor. The 150, 350 and 3,000 foot ranges and the model range are visible in this northwest view across one section of range land. The tower in the left foreground is one terminal of the 3,000 foot range leg. A more detailed description of the tower is shown in Fig. 10. Any of the distant towers may be used as the second terminal of the long range leg. If ranges greater than 3,000 feet are required under special circumstances mountain peaks at nominal ranges of five, seven, fifteen and twenty miles may be used. General weather conditions permit measurement operations about 90 percent of the time while maintenance is accomplished during the remaining time resulting in nearly 100 percent use time. Measurements may be made after hours when necessary. The principal detrimental weather factor is wind during March and April if very large antennas are employed in tests.

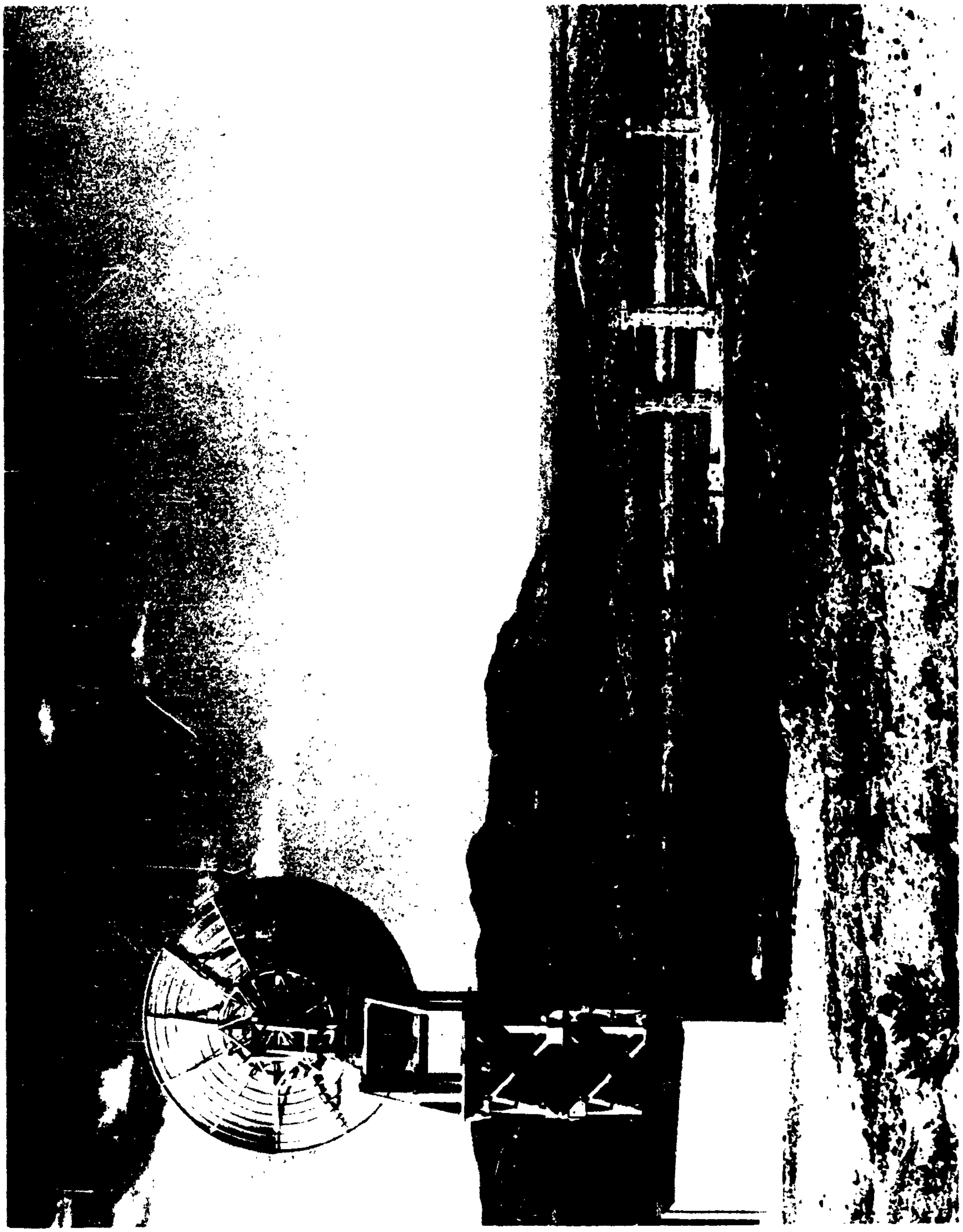


FIG. 4 - THE MAIN AREA OF THE PSL/NMSU ANTENNA RANGE

This isolated area two miles east of the NMSU campus is ideal for radiation pattern measurements. Four ranges are in the area. The 350 and 150 foot long ranges are shown in this photograph. The transmit tower in the center is a common terminal for three of the range legs and any of these towers may be used as a terminal point for the 3, 000 foot range leg. The center tower is 80 feet high with the axis of the transmit antenna at the 85 foot level. The north and south receiver towers are 70 feet high. The test antennas may be elevated an additional 15 feet on a Fiberglas column, thus the antenna "space platforms" are a minimum of 85 feet above ground level. The model range and the 3, 000 foot range extend toward the mountain and are not visible in the photograph. Refer to Fig. 2 for the general arrangement of the range. In less than twelve months more than 15, 000 precision radiation patterns have been recorded.

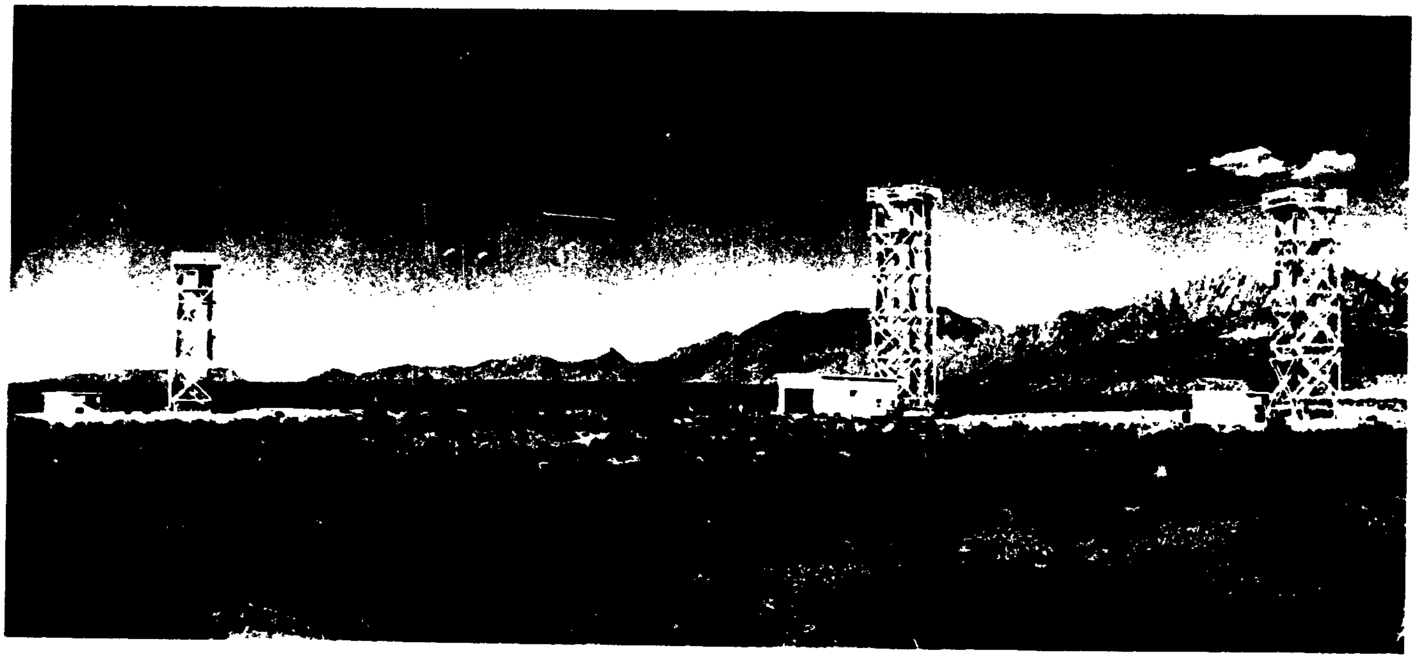


FIG. 5 - TRANSMITTER TOWER AREA
OF THE ANTENNA RANGE

The 80 foot high transmit tower is the center tower shown in Fig. 4. A 250 Mc transmitting helix antenna is mounted on the top deck and is directed toward the south receiver tower. The ground level building is used for storage and housing of test equipment in antenna range activities. The model range tower with a horn attached to the mounting head is shown in the lower right portion of the photograph. The small platform on the right side of the tower, about 15 feet above ground level, supports the polarization positioner for the model range and provides personnel working space when the model rotator column is moved up to the main tower. Further details are shown in Figs. 8 and 9 .

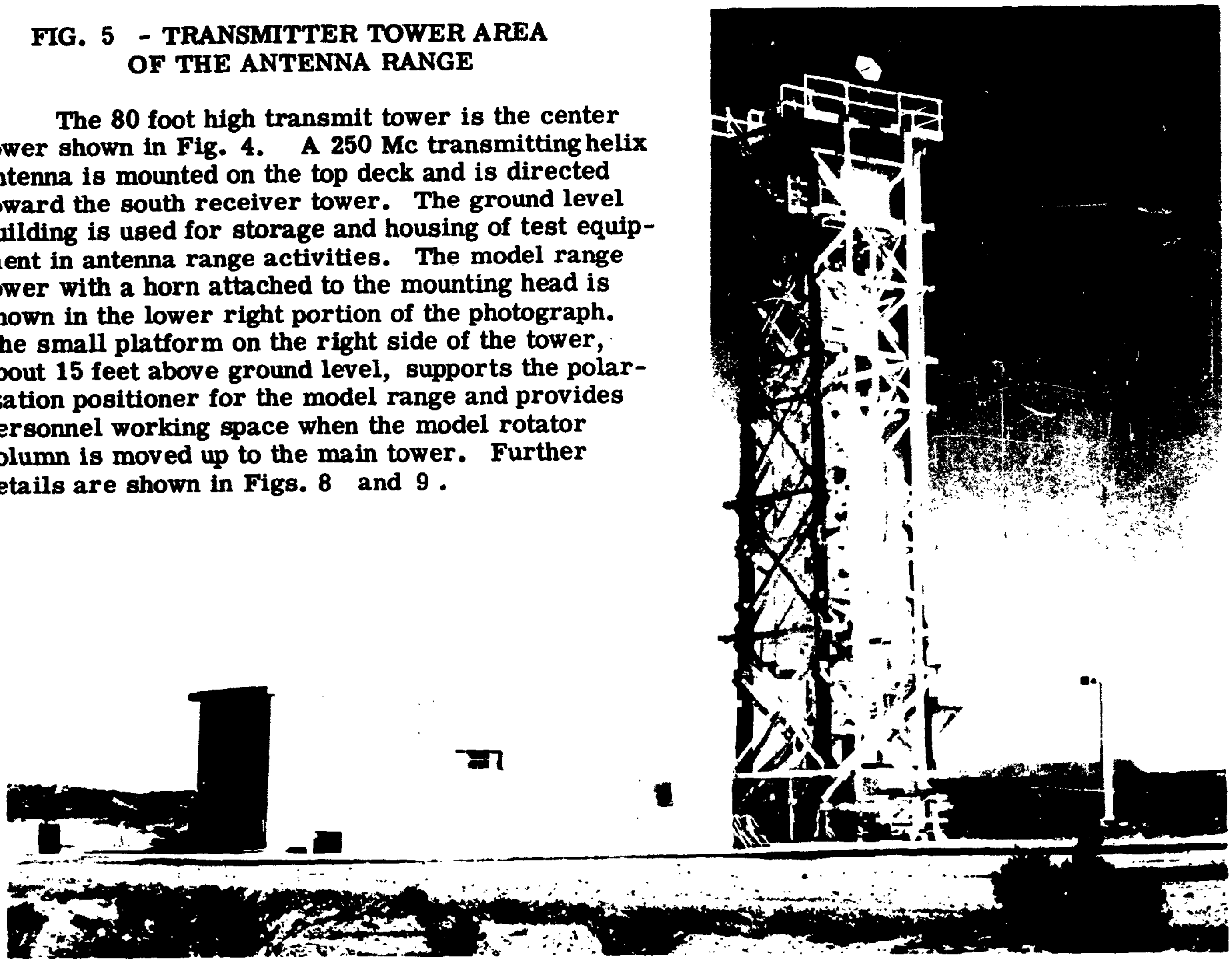
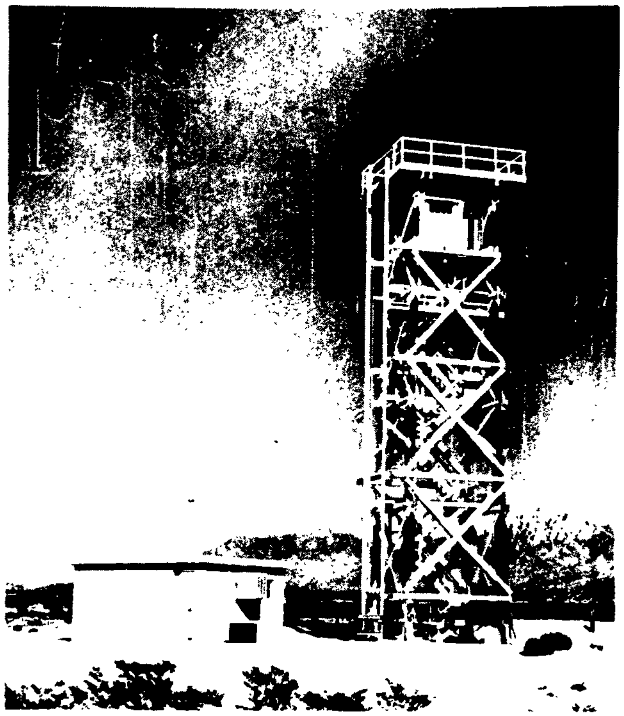
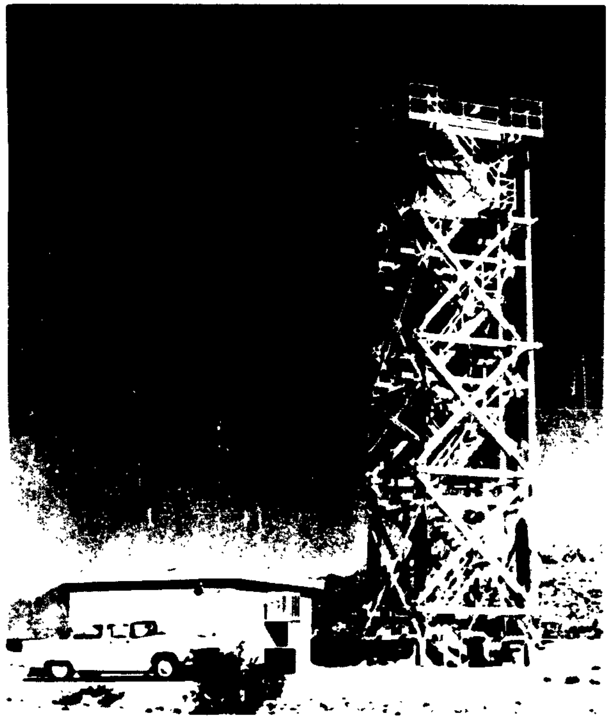


FIG. 6 - NORTH AND SOUTH RECEIVER TOWERS AND ASSOCIATED RECORDING INSTRUMENTATION BUILDINGS LEFT AND RIGHT PHOTOGRAPHS RESPECTIVELY

The height of each receiver tower is 70 feet above the tower base and is designed to withstand a wind velocity of 100 mph with an appropriate safety factor. Personnel access to any level of the tower is via the stairway. One side of each tower is provided with an equipment hoist which has a 1,200 pound capacity. The lift cable is nylon rope to maintain radio frequency scattering at a minimum. The 16 X 16 foot pattern recorder instrumentation buildings are climate controlled for equipment stability and personnel comfort.





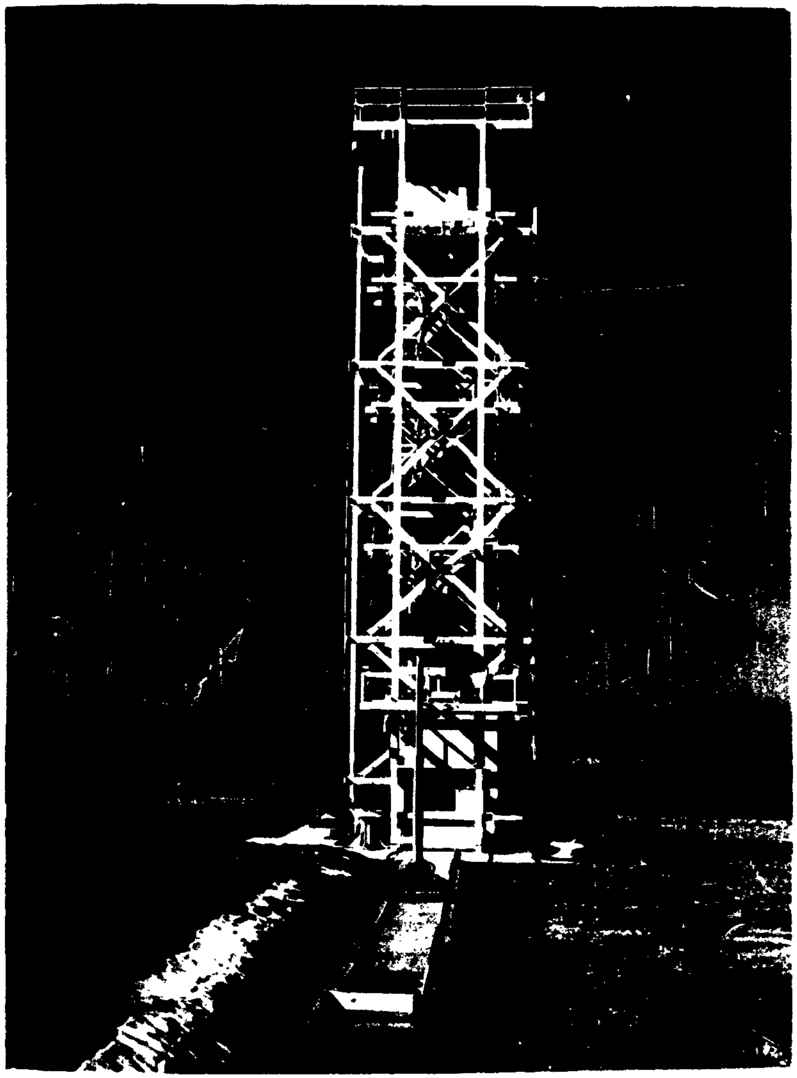


FIG. 7 - VARIABLE LENGTH ANTENNA MODEL RANGE

This is a westward view of the model range. It is used for model measurements, preliminary data on basic radiator types and some full scale measurements at the higher radio frequencies. The tower in the background is the center tower of Fig. 4 . Two transit antennas are mounted on the top platform and are directed toward the north and south receiving towers. The model tower can easily be positioned at any distance along the 100 foot track. Additional features are shown in Figs. 8 and 9 .

FIGS. 8 (LEFT) AND 9 (RIGHT) ANTENNA MODEL RANGE

The model antenna positioner is mounted on a four wheel cart for positioning the antenna at the required distance from the tower platform. The positioner provides for azimuth rotation of the antenna about the vertical axis of the rotator unit on the cart platform and rotation about the horizontal axis of the uppermost portion of the column. The column is fabricated entirely of Fiberglas and other dielectric materials which keep reflections at a minimum. In this photograph a horn antenna has been mounted on the rotator mounting face. A coaxial rotary joint is used on the back end of the mounting head to which a transmission line may be connected. Other arrangements are possible. In this particular arrangement a backward wave oscillatory in the rectangular box on the cart is used to deliver rf energy to the horn. In this mode of operation, the parabolic antenna on the tower platform is the receiving radiator which is connected to the receiver and pattern recorder console in the ground level room. The backward wave oscillator units are remotely tuned from the recorder console.

The parabolic antenna, or alternate desired types, are mounted on an antenna positioner. It is a light duty unit similar to the heavy duty positioners on top of the main towers as described in Fig. 14.

Access to the tower head is accomplished by rolling the unit up to the tower working platform.

FIG. 10 - ANTENNA LONG RANGE TOWER

This antenna tower is at one terminal of the 3, 000 foot range leg. Structurally it is designed to support a 30 foot diameter solid surface parabolic reflector within a 80 mph wind. A 19 foot diameter parabolic reflector has been mounted for radiation pattern analysis of a broadband nutating feed system to be employed in deep space communication. The antenna is attached to an azimuth positioner for rotation and the positioner rests on an elevator hoist which is guided by four vertical columns. Antenna adjustments are made at ground level and raised to the test position. The receiver or transmitter is located in the ground level building as required.

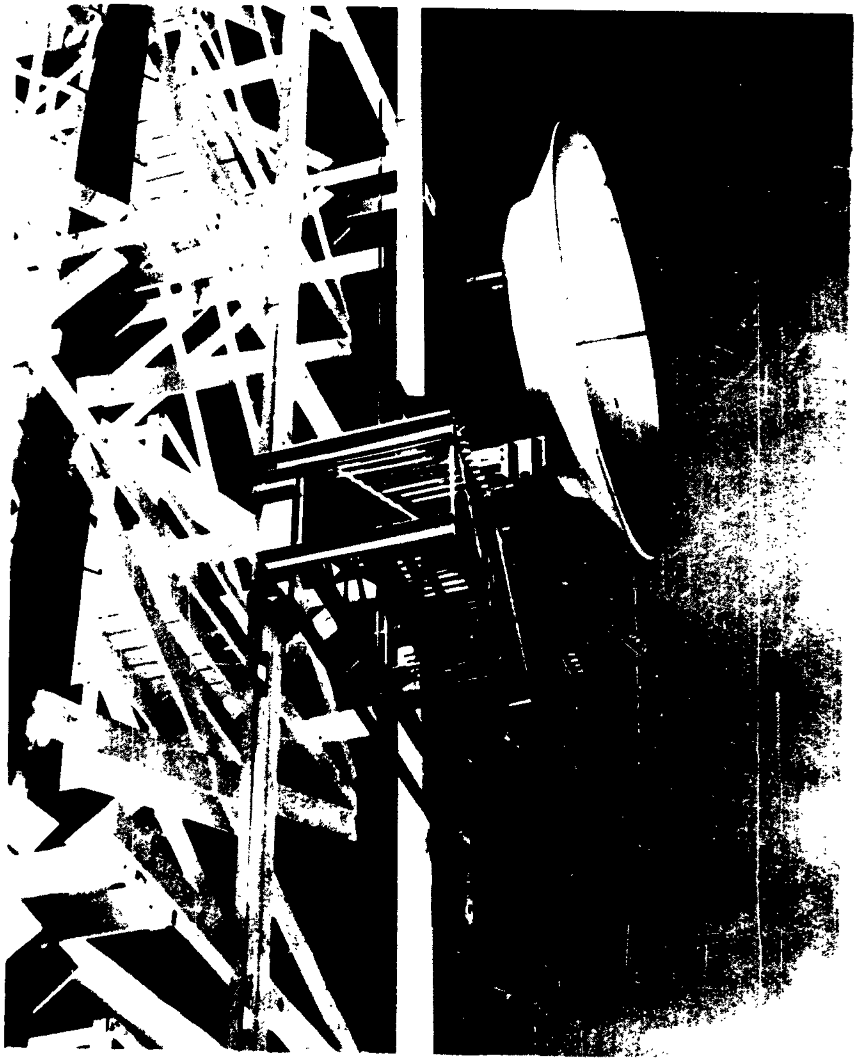


FIG. 11 - TRANSMITTER TOWER POLARIZATION POSITIONER AND TRANSMIT ANTENNA BEING RAISED TO THE TOP OF THE TOWER

This is a typical transmitter antenna setup. In most instances parabolic reflectors and horns are used for frequencies above 400 Mc. Helical and Yagi antennas are generally used below 400 Mc.

The antenna setup procedure is designed to rapidly change antennas at ground level. Universal adapters for each class of antenna have been designed for the interface between the polarization positioner and the transmitter element.

FIG. 12 - TRANSMIT ANTENNA ARRANGEMENT

This photograph shows a 10 foot diameter parabolic reflector being raised to the upper deck of the transmit tower. Various linear and circularly polarized feed systems are employed in several size parabolids. Antennas at the top of the tower may be fed from oscillators located at the top of the tower, in the ground level building below or other remote locations via coaxial cable or waveguide as applicable to the particular type of problem.

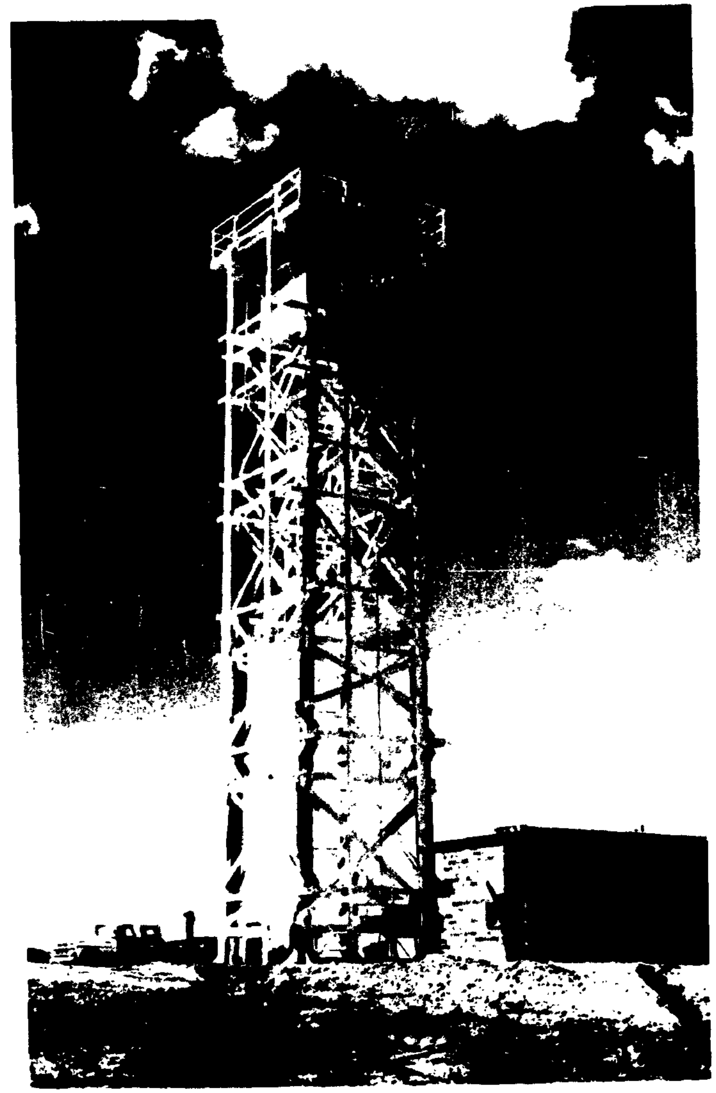


FIG. 13 - TEST ANTENNA MOUNTING ARRANGEMENTS

In order to obtain maximum versatility it was found desirable to provide an antenna mounting arrangement that would satisfy a wide variety of conditions. A Fiberglas flange is permanently bonded to the upper end of the column which permits a variety of mount types to be easily bolted on with nylon bolts. Two of the many mounts available are shown in the photograph. These tubular tee sections are fabricated of Fiberglas. End plates, such as those shown on the small tee section, are available for a large variety of missile mockups. Polyfoam supports are sometimes used in lieu of Fiberglas as conditions warrant.

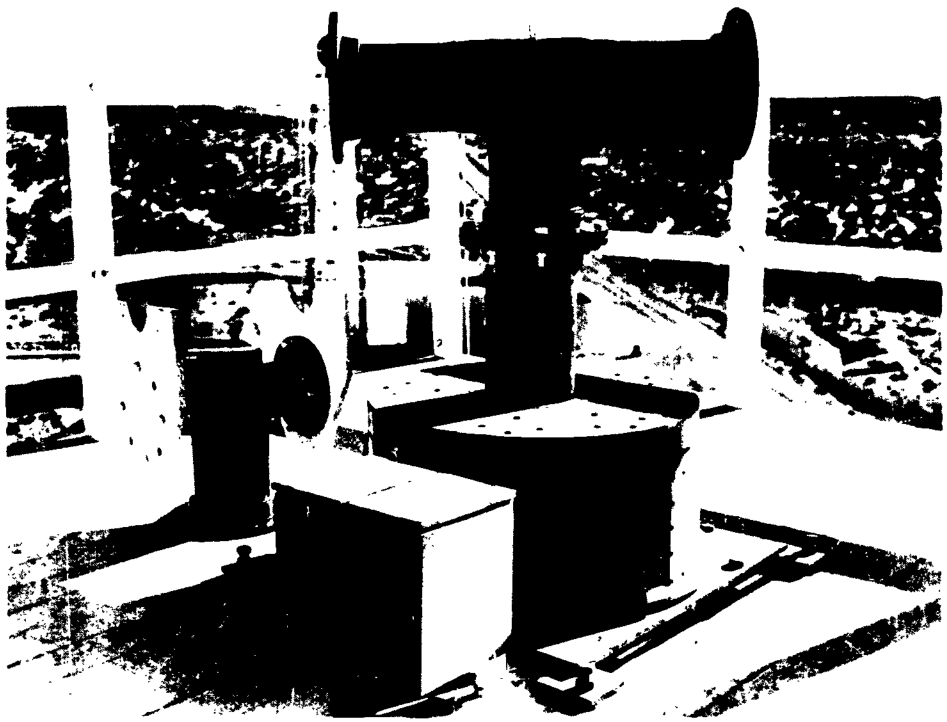


FIG. 14 - ANTENNA POLARIZATION POSITIONER

Three polarization positioners are located on the transmitter tower. Two of these are heavy duty units on the top deck of the tower; one of which is shown in the photograph. A light duty unit is employed with the model range as shown in Figs. 8 and 9. The units are used to support and position various transmitting antennas employed in tests. A horn antenna is shown mounted in this photograph. The positioner is designed to support solid surface fifteen foot diameter parabolic antennas under 80 mph wind conditions. The antennas may be rotated 360° about the horizontal axis or any increment thereof by an appropriate setting of the limit switches. The rotation of the transmit antenna may be synchronized with the recorder when desired to obtain a polarization ellipse. Recording time per polarization ellipse is 20 seconds. The supporting unit is a four-wheel cart which rides on and may be locked to the top deck rails. The hoist for these units is shown in Fig. 11. When the hoist is at maximum height the rails on the hoist are match aligned and lock with the platform rails allowing the polarization positioner to be moved onto the hoist and transported to ground level for changing of antennas rapidly and safely.

The rectangular container mounted on the lower right side of the cart houses one of the remote controlled oscillators connected to the horn above through a coaxial rotary joint on the rear of the positioner. The tee coupler just behind the rotary joint is used to pick off the receiver AGC signal.

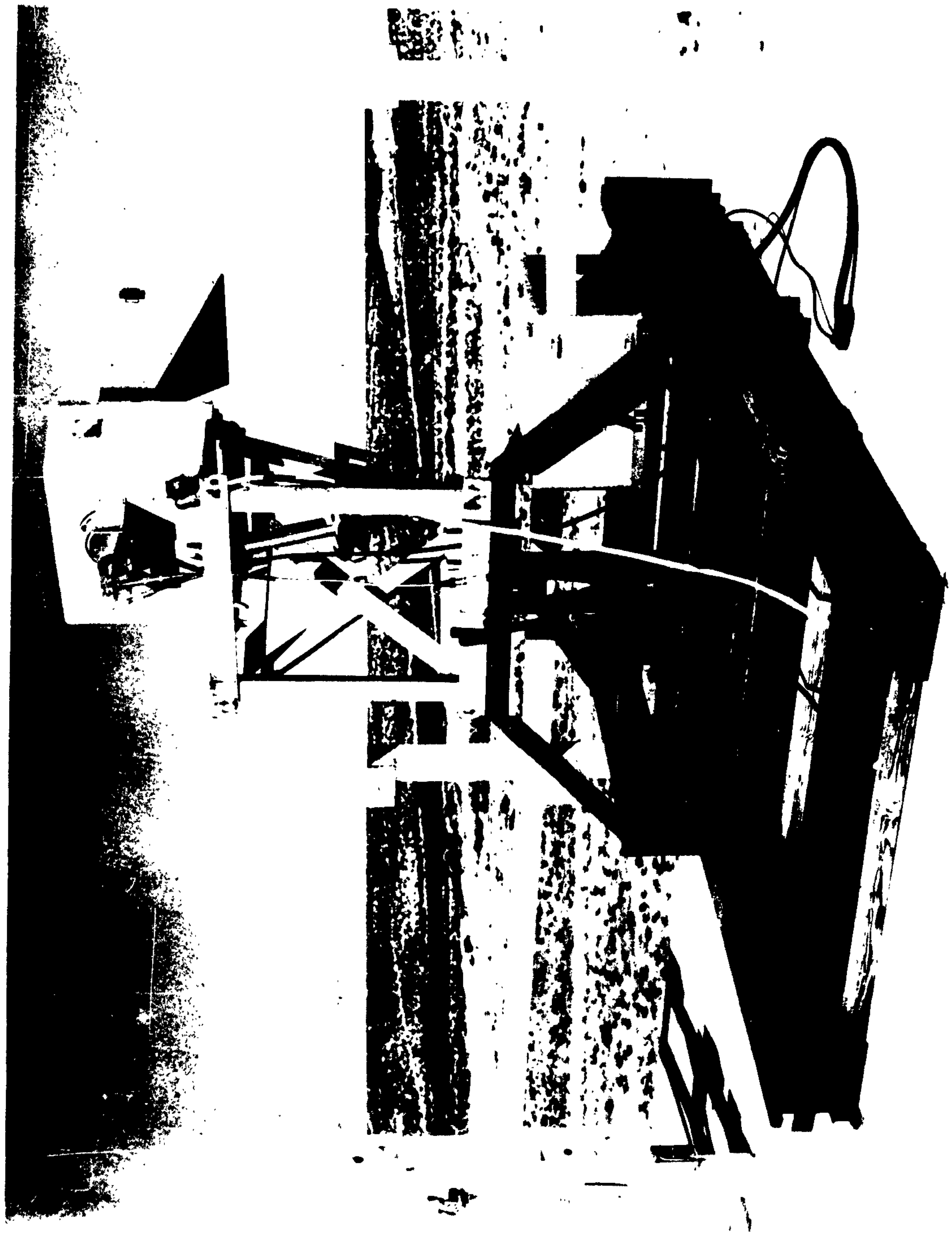


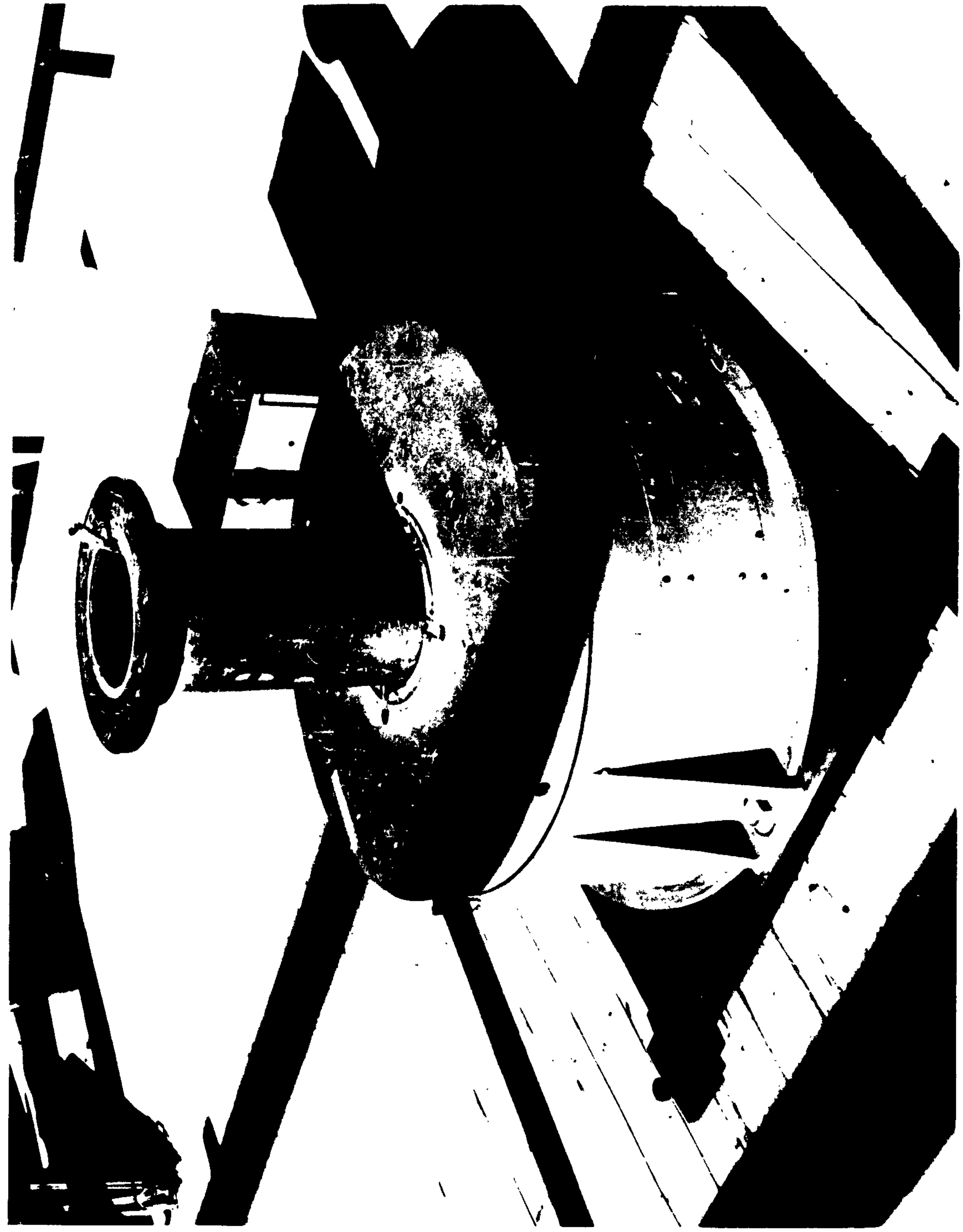
FIG. 15 - TYPICAL HEAVY DUTY AZIMUTH ANTENNA POSITIONER

These antenna positioners are located on the top platform of the north and south receiver towers and have been especially modified to accept an eight-inch diameter Fiberglas tubular column. The column is the support structure to which test antennas are attached and may be elevated from three inches to sixteen feet above the positioner top surface. The column is keyed and rotates with the azimuth turntable. Angular azimuth position is controlled from the receiver console. The column height may be controlled from the receiver console or by personnel in the immediate vicinity of the positioner with a stop override switch at each station. Two sets of limit switches are employed with column height motion. One set limits extreme travel of the column and the other set may be adjusted to any two intermediate positions for normal operations. When required, the column may be fully retracted and other devices may be bolted directly to the turntable surface. A 16 channel slip ring for monitoring or controlling of other functions above the turntable is provided. The positioner may be rotated continuously in azimuth in either direction.

In the usual mode of operation a coaxial line passes through the column from the test antenna to a rotary joint at the base of the column thence to the receiver. In instances where the presence of this line causes pattern perturbations battery powered oscillators may be used and the usual receive - transmit mode reversed. The inside diameter of the column is large enough to accept waveguide when technically necessary or desirable.

The rotator unit is attached to rotator mount unit which is designed to transmit the loads to the tower structure. The rotator mount also incorporates the column alignment and lift mechanism directly under the mounting plate.

The tower top deck is capable of supporting a 6,000 pound compressive load concentrated on the azimuth turntable. Similar loads up to 1,200 pounds may be placed on the end of the Fiberglas column. The column maximum load is primarily limited by allowable column deflection attributable to wind load, antenna size, etc.



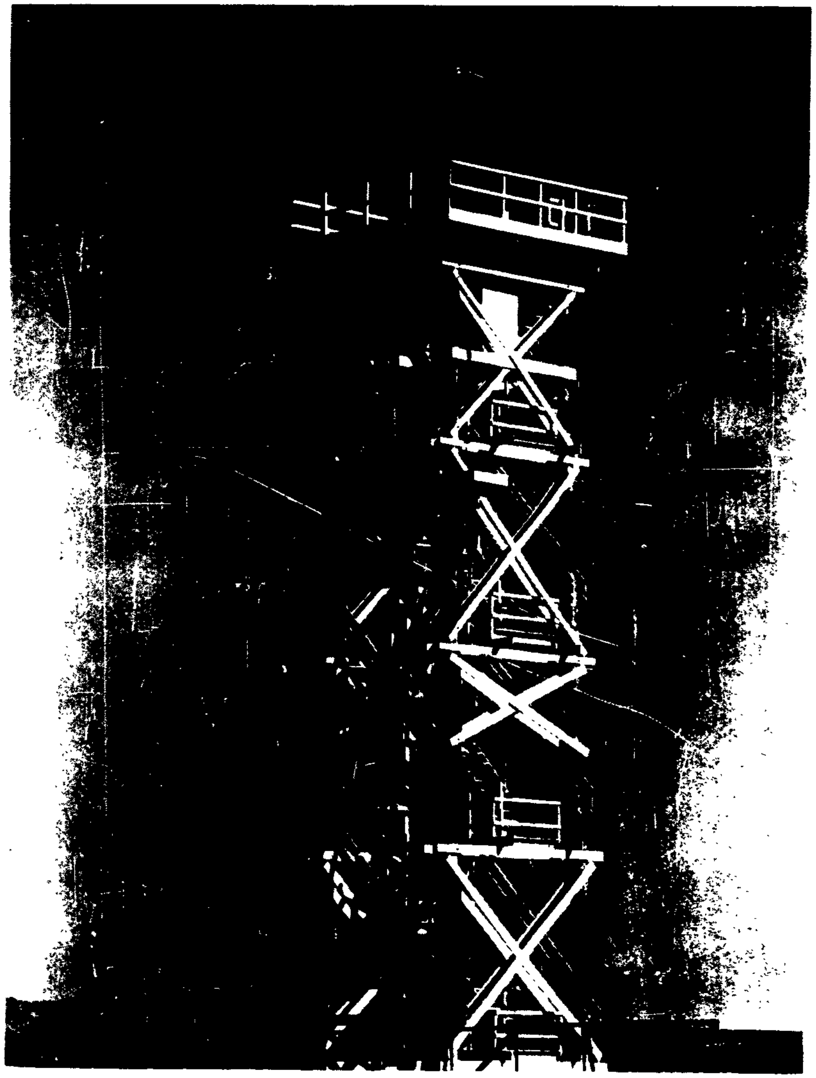


FIG. 16 - ANTENNA RANGE CALIBRATION

A rapid means of measuring the standing wave field within the space volume in which the test antenna is to be placed is provided for. This photograph shows a half-wave dipole being used as a field probe. The position of the probe can be moved radically with respect to the main Fiberglas support column which in turn may be moved up and down as well as rotate in azimuth. This data is measured for each test antenna setup to ensure optimum data quality.

FIG. 17 - TRANSMIT HELIX ANTENNA

This is a typical helix antenna mounting on the polarization positioner at the top of the transmitter tower. In this photograph it is facing the south receiver tower illuminating a test antenna with a right circularly polarized wave.

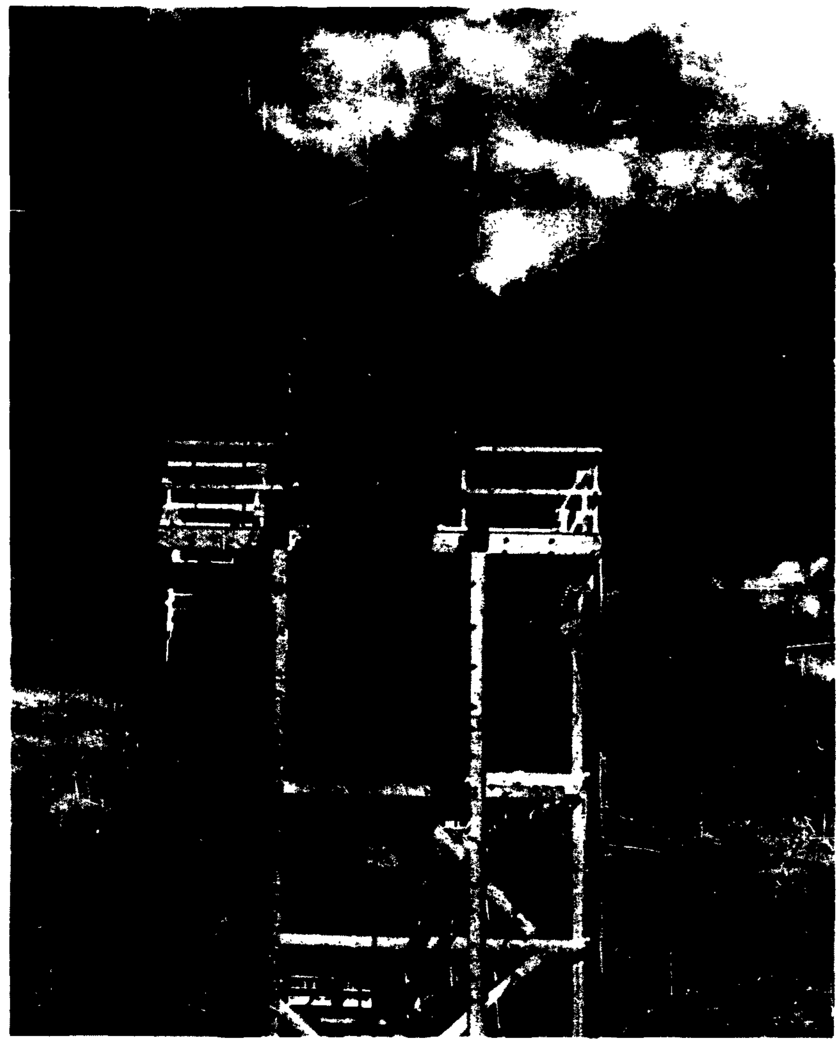


FIG. 18 - TYPICAL RADIATION PATTERN MEASUREMENT CONSOLE ARRANGEMENTS

The receiver unit, on the left, has a frequency range of 30 Mc to greater than 75 Gc. The center unit is a polar recorder and bolometer amplifier. The unit on the right consists of 1:1 and 36:1 synchro indicators to display angular position of antenna positioners, polarization positioners and receiver antenna height-above-tower-top indicator.

Other panels in this unit include the recorder pen program polarization-kind code, remote voltage tuneable oscillator control and antenna positioner controls. For maximum versatility it has been found desirable to arrange the units as shown. In this manner complete units or portions thereof may be interchanged throughout the range. Four complete consoles of this type are in use on the range. Two of the receiver units have a 20 and 40 db dynamic range and the other two have a 20, 40 and 60 db dynamic range. One rectangular chart recorder, not shown, is also available for use on any range.

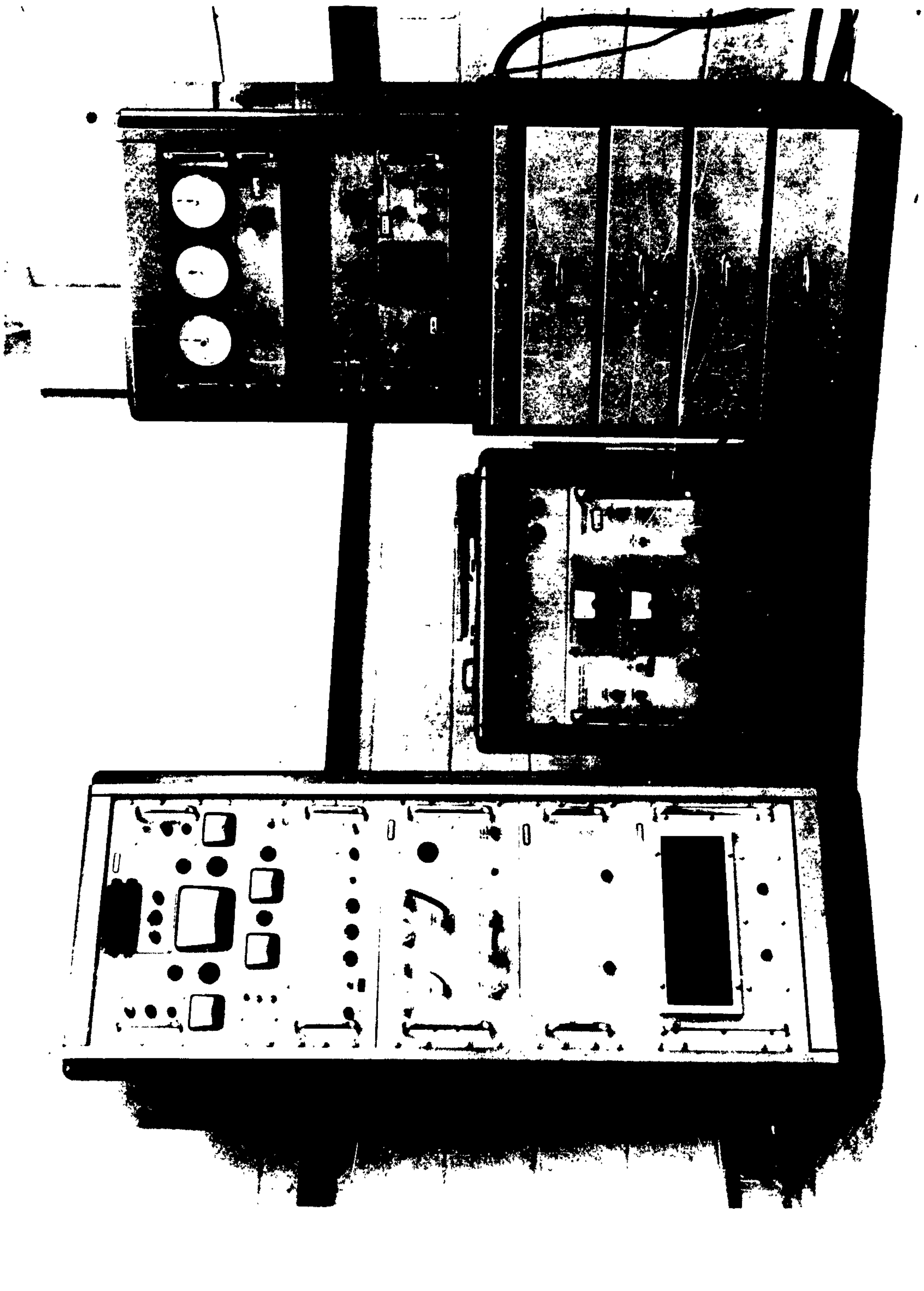


FIG. 19 - TYPICAL ANTENNA TEST MOUNTING ARRANGEMENTS

A JAVELIN 803 payload section with telemetry quadraloop antennas is mounted on a polyfoam support which is in turn attached to the Fiberglas support column by means of a Fiberglas tee adapter. Due to the complex ground plane structure the actual payload was employed for final tests.

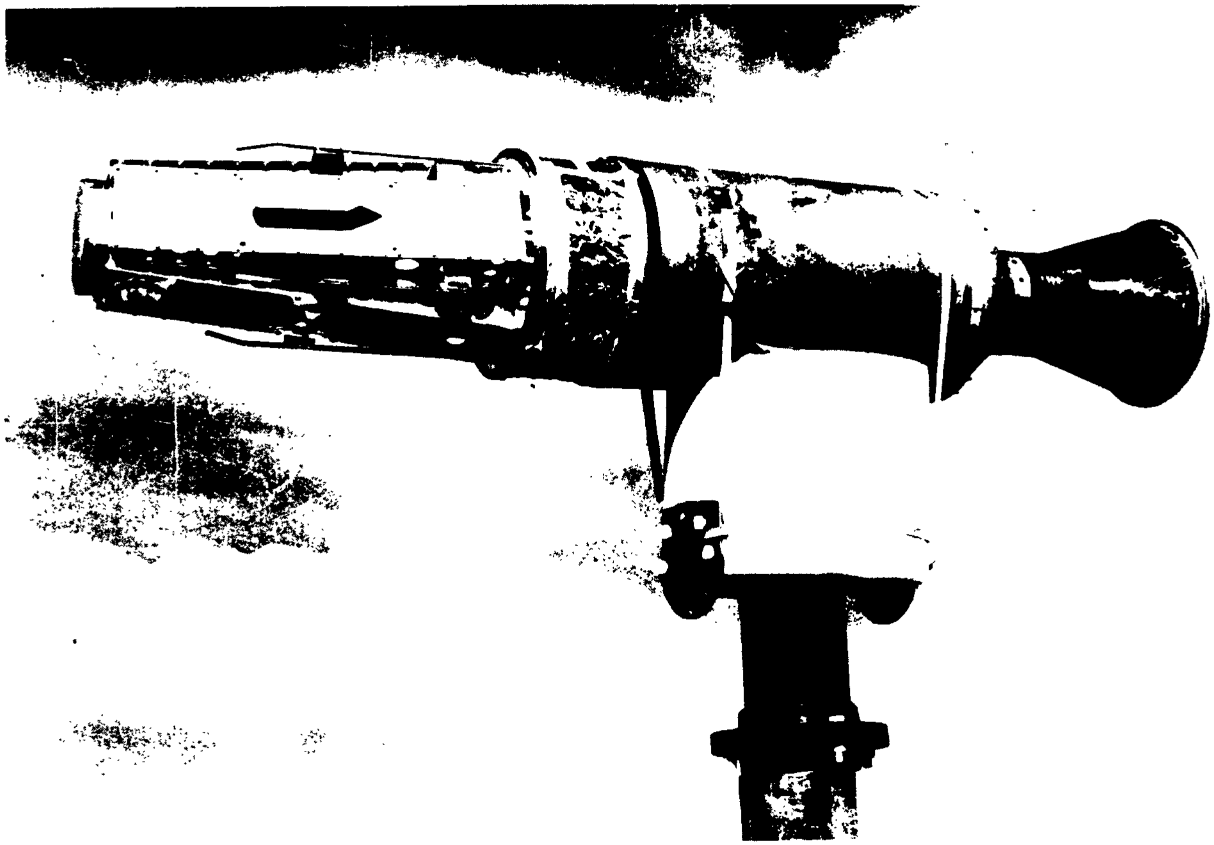
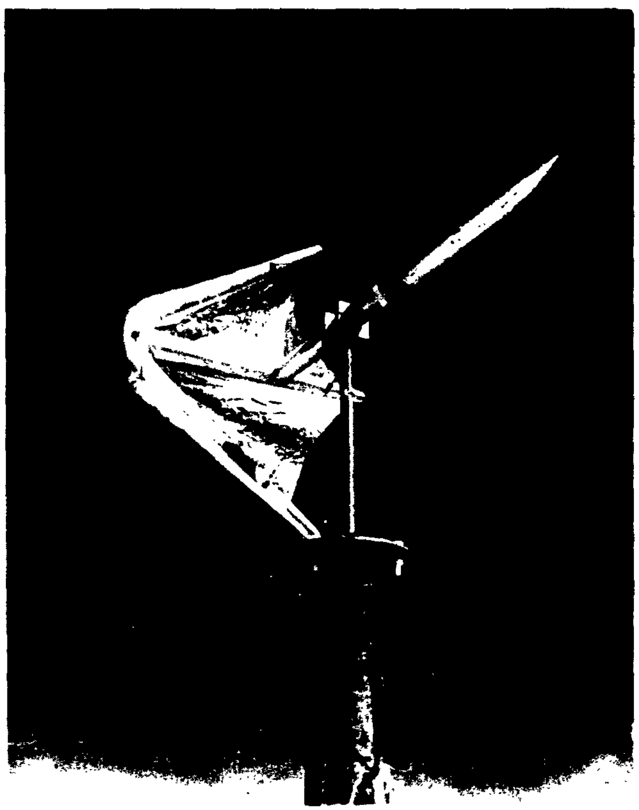


FIG. 20 - TYPICAL ANTENNA TEST MOUNTING ARRANGEMENTS

Lower Left - A one-quarter scale model of the **AEROBEE** paraglider configuration mounted on the receiver tower for telemetry antenna patterns. Full scale tests will be conducted at a later date.

Lower Right - A full scale **NIKE-HERCULES** missile employed for evaluation of a bent-valentine beacon transponder antenna system is shown mounted on the receiver tower Fiberglas column support.



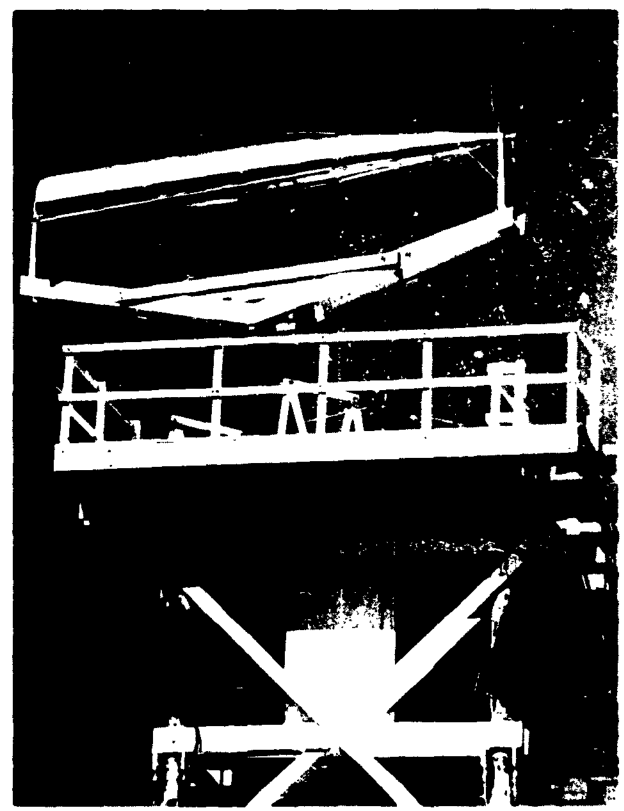


FIG. 21 - TYPICAL ANTENNA TEST MOUNTING ARRANGEMENT

A TYPHON missile mockup section with telemetry antenna attached is mounted on a receiver tower column adapter unit for radiation pattern analysis.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the efforts of the University staff, Federal Bureau of Land Management, New Mexico State Agencies and many other groups who assisted in the program together with individuals whose suggestions and efforts significantly contributed toward making this endeavor a reality. Dr. R. H. Duncan, Supervisor, Electromagnetics Group 1955-1960; Professor M. D. Creech, Structures Consultant; P. Manz, Machine Shop Superintendent, special equipment; and L. L. Snow the present antenna range engineer who put the system together and placed it in operation. In addition, the members of the Physical Science Laboratory, New Mexico State University Electromagnetics Group assisted in various design problems and our undergraduate students made valuable contributions in all phases of the program.

Appreciation is expressed to the P. R. Burn Construction Company for their efforts in constructing the towers and buildings and to the Scientific-Atlanta Company for the excellent quality of antenna range instrumentation equipment.

SPECIAL ANNOUNCEMENT

As this report was completed the American Telephone and Telegraph Company had very generously presented the New Mexico State University with the abandoned microwave building, tower and access road on top of Tortugas Mountain. This gift by AT & T will very materially compliment the Physical Science Laboratory electromagnetic endeavor in the area and become an integral plant of the radiation pattern measuring instrument and other related research activities. Its location and arrangement is particularly well suited for certain types of measurements.

The building and tower noted are shown in Fig. 22 below.